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Buckley

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(54) **ELECTRIC DRIVE PUMP FOR WELL STIMULATION**

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CPC ***F04B 17/03*** (2013.01); ***E21B 43/26*** (2013.01); ***F04B 53/16*** (2013.01); *F04B 47/02* (2013.01)

(58) **Field of Classification Search**
CPC E21B 43/26
See application file for complete search history.

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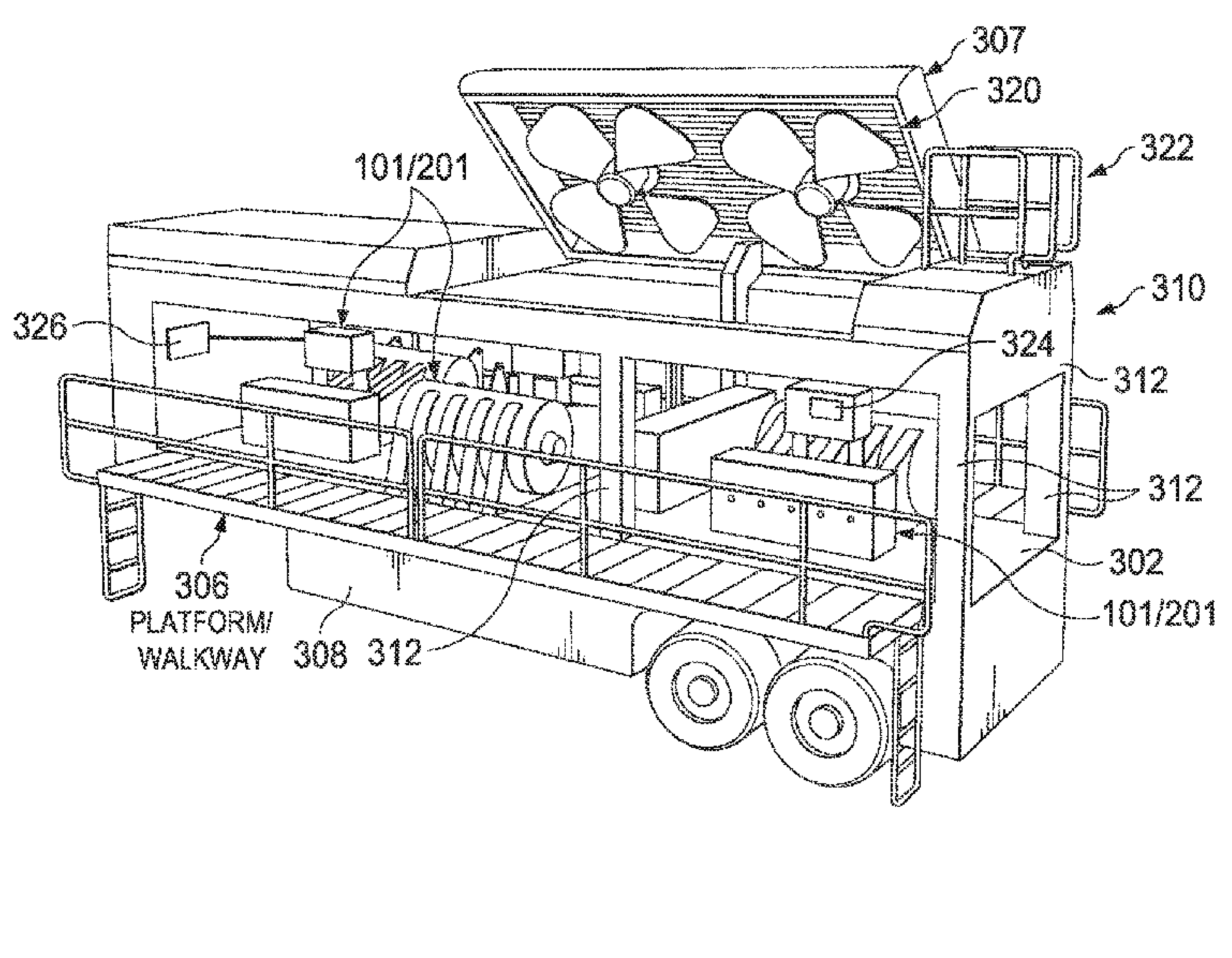
(57) **ABSTRACT**

An electric drive pump system includes a power end and a detachable transmission assembly. The transmission assembly is mounted to the power end and is configured to provide rotational power to the power end through a plurality of electric motors. The plurality of electric motors use a gearbox to drive an output spline that engages the power end. A control module is used to regulate the performance characteristics of the plurality of electric motors. A temperature regulation assembly is configured to regulate the temperature of the transmission assembly and the power end.

21 Claims, 13 Drawing Sheets



(51) **Int. Cl.**
F04B 53/16 (2006.01)
F04B 47/02 (2006.01)

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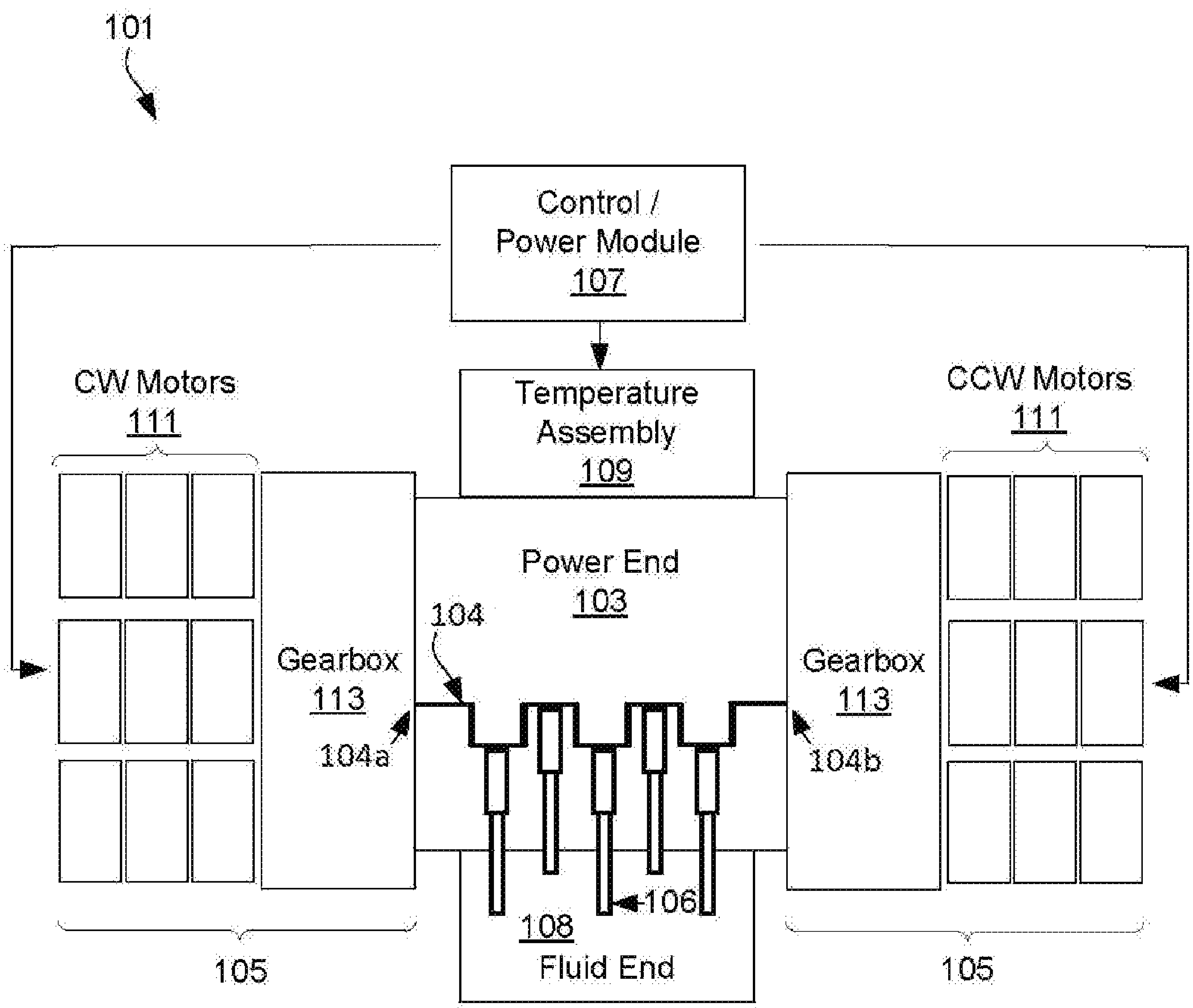

101
Control /
Power Module
107
Temperature
Assembly
109
CW Motors
111
CCW Motors
111
Power End
103
104
Gearbox
113
104a
Gearbox
113
104b
106
108
Fluid End
105
105

FIG. 1

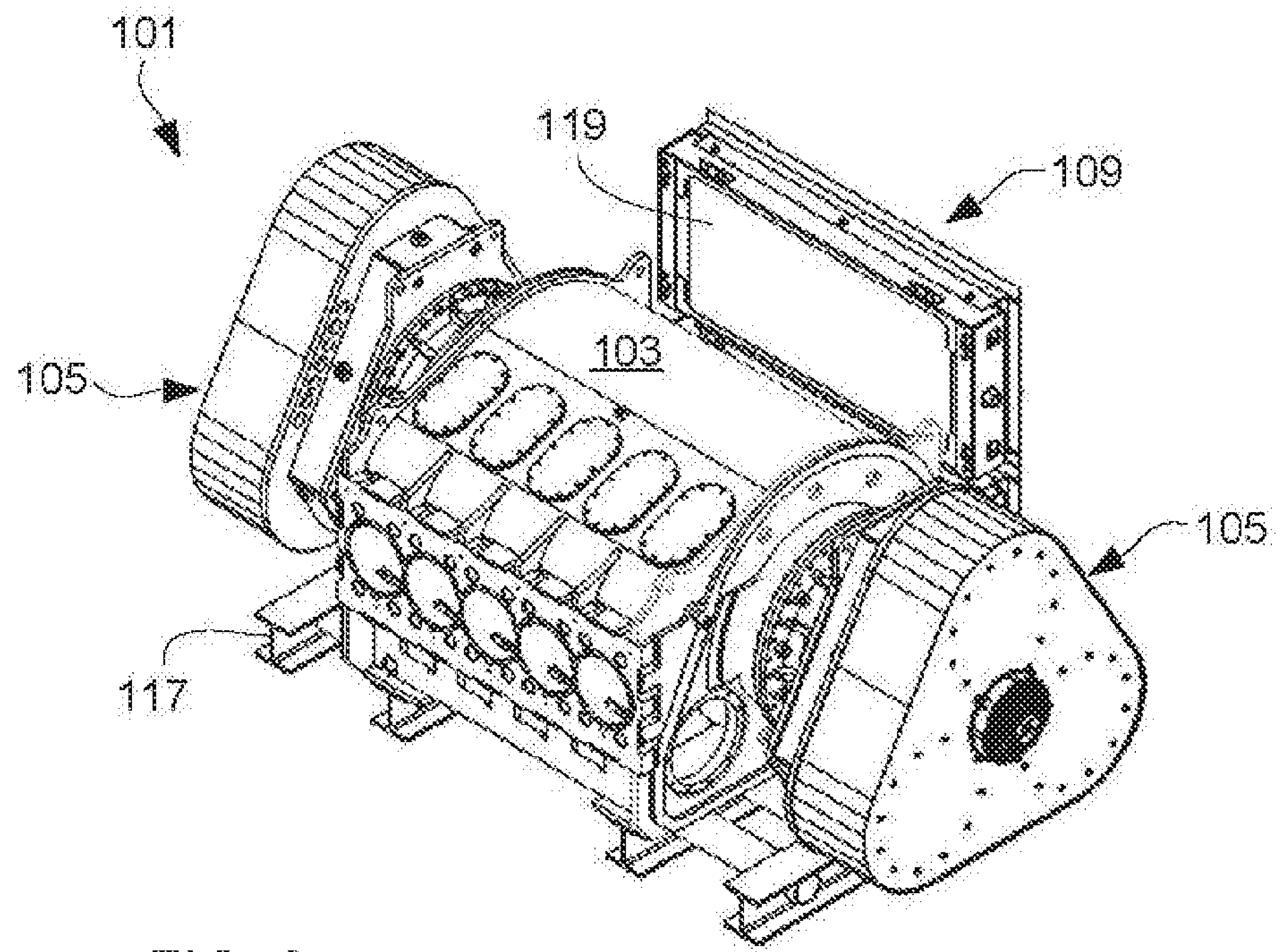


FIG. 2

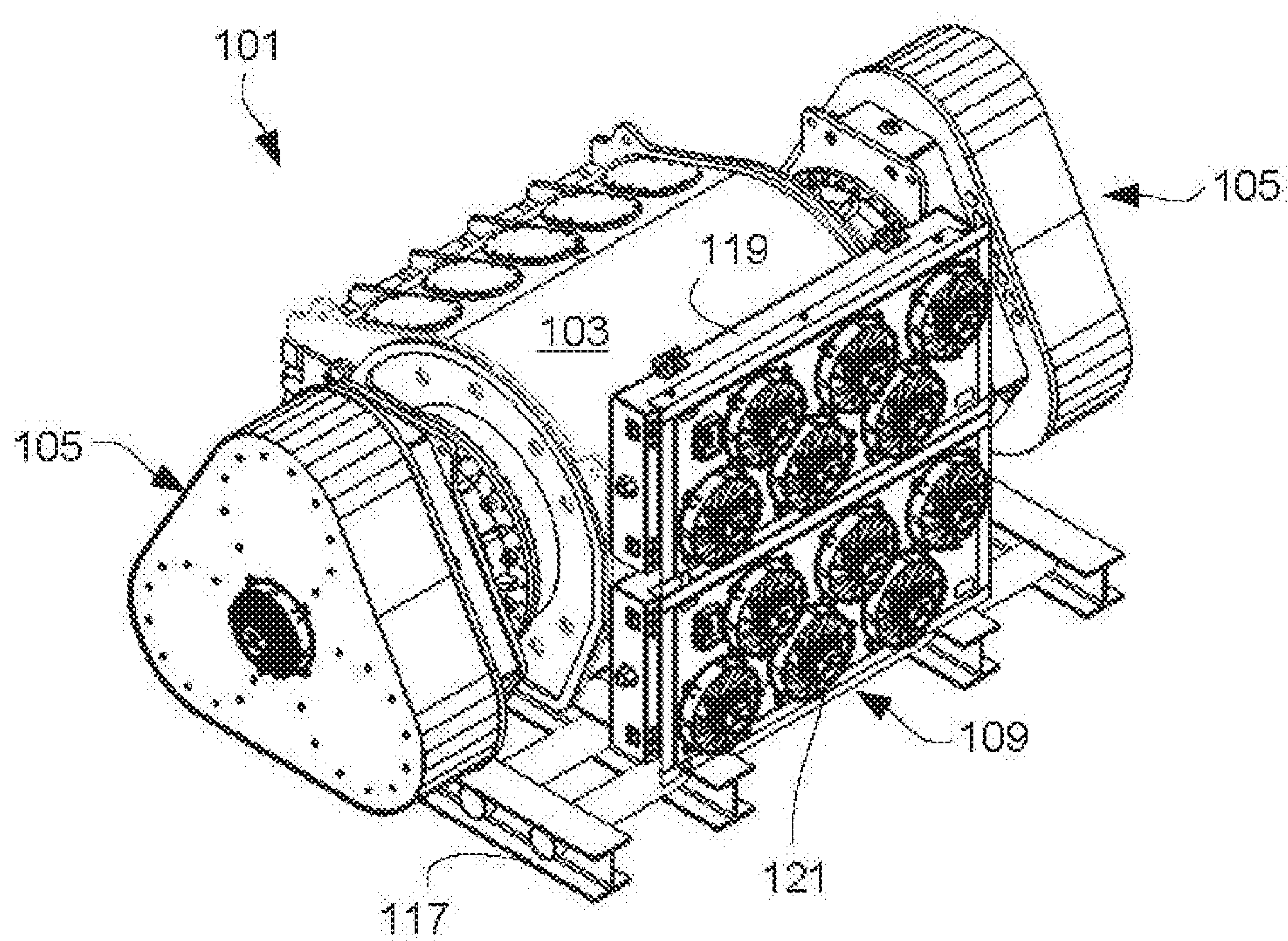


FIG. 3

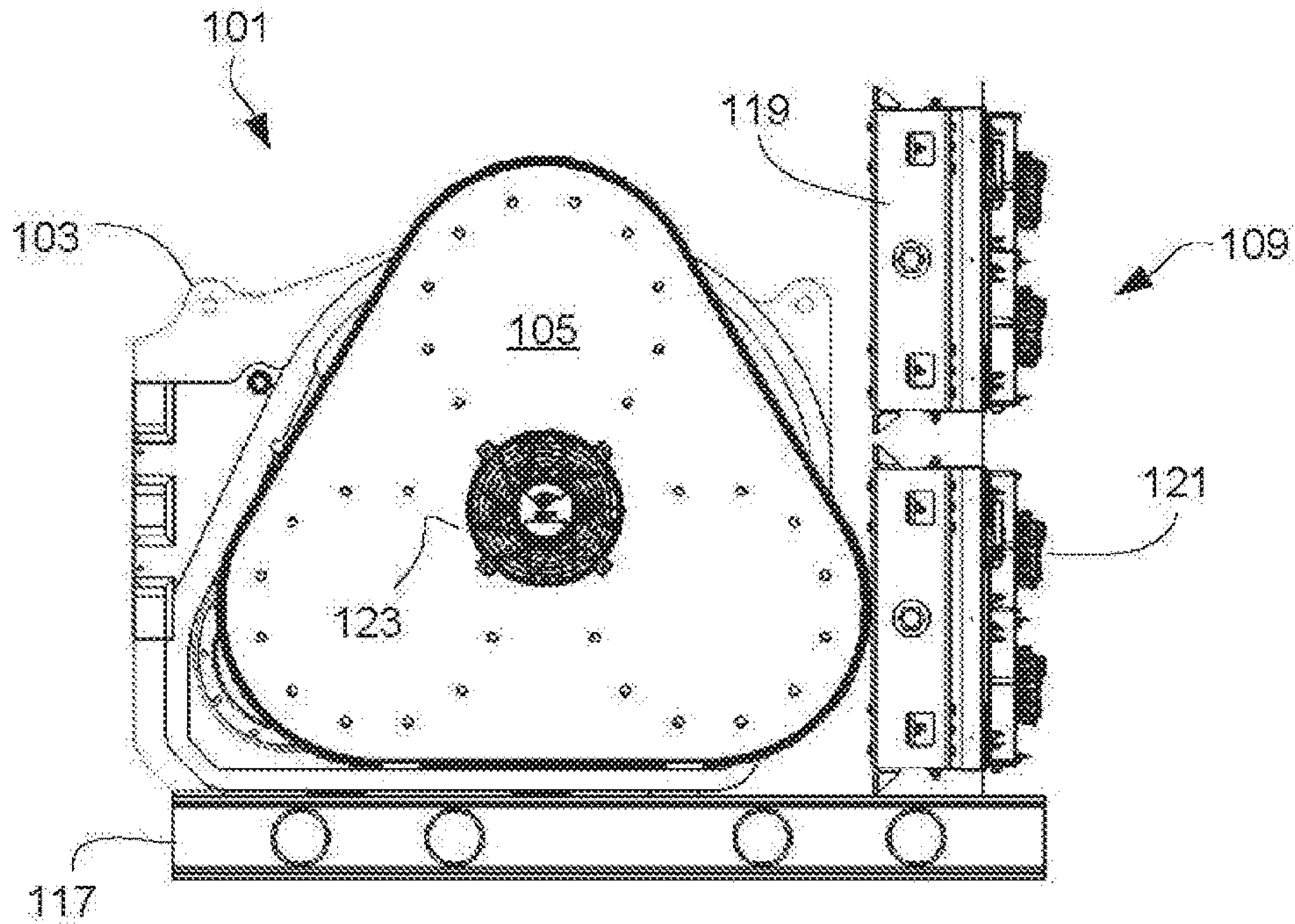
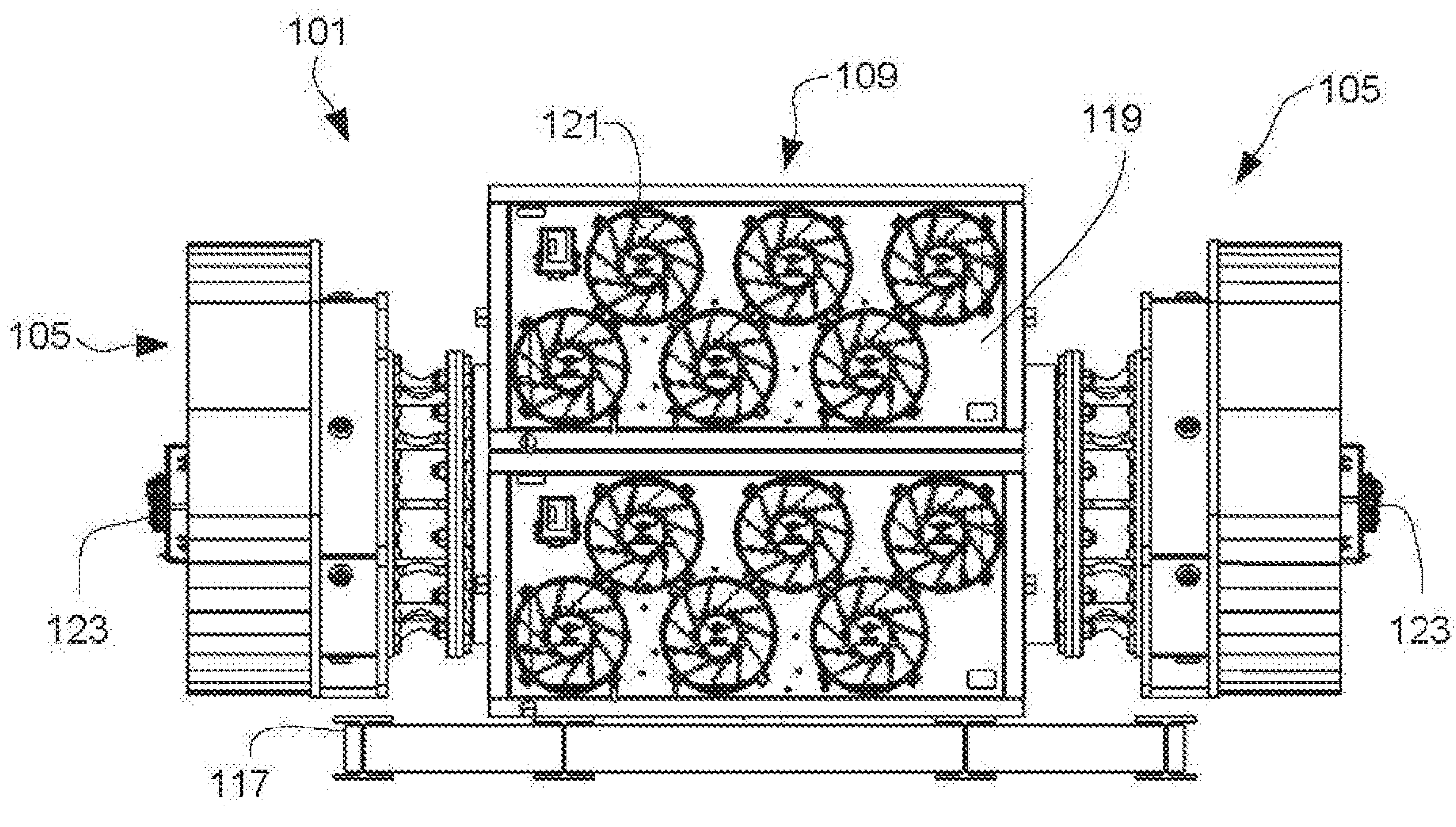

101
119
103
109
105
121
123
117

FIG. 4


101
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121
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105
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123
117

FIG. 5

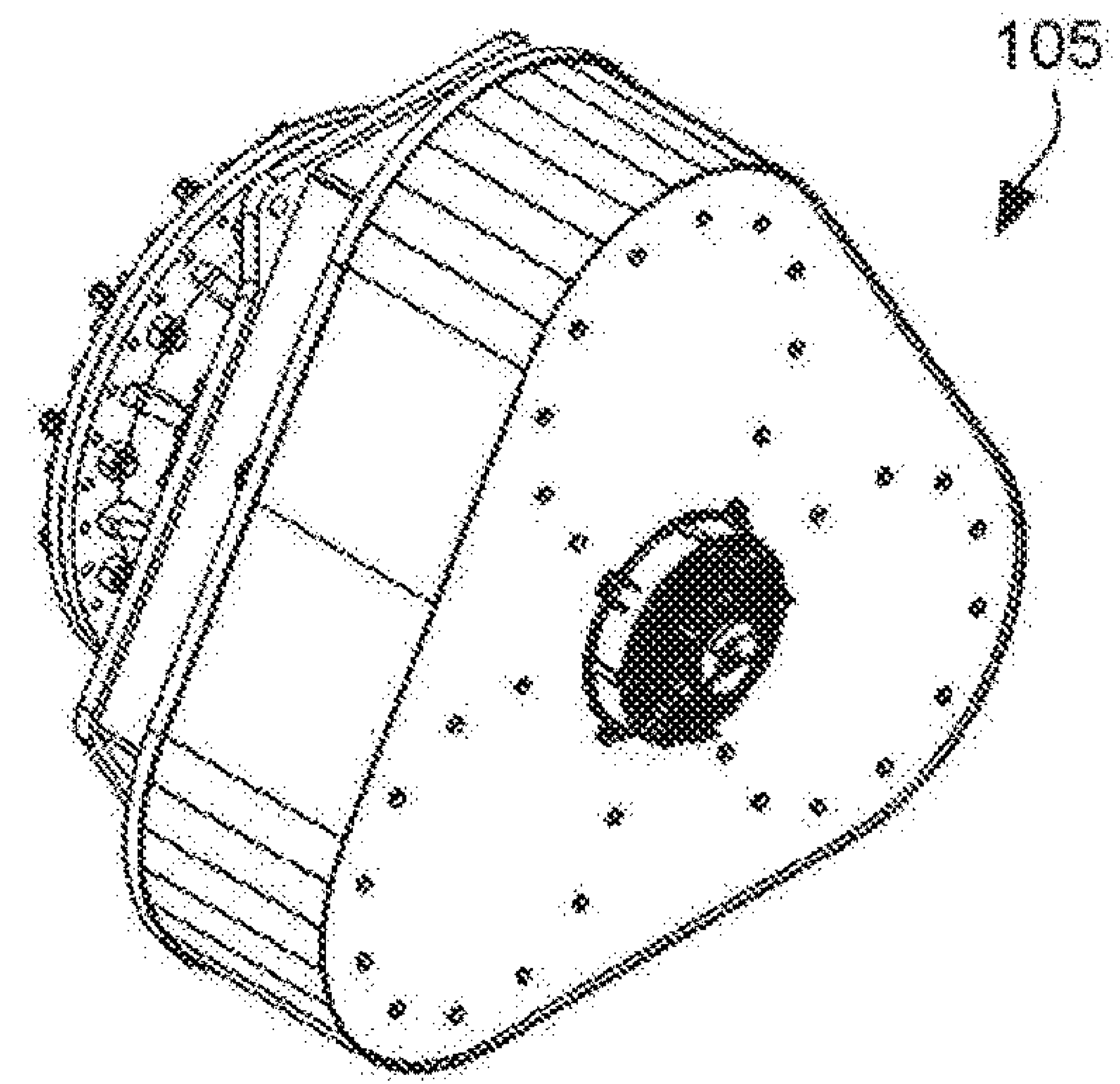

FIG. 6

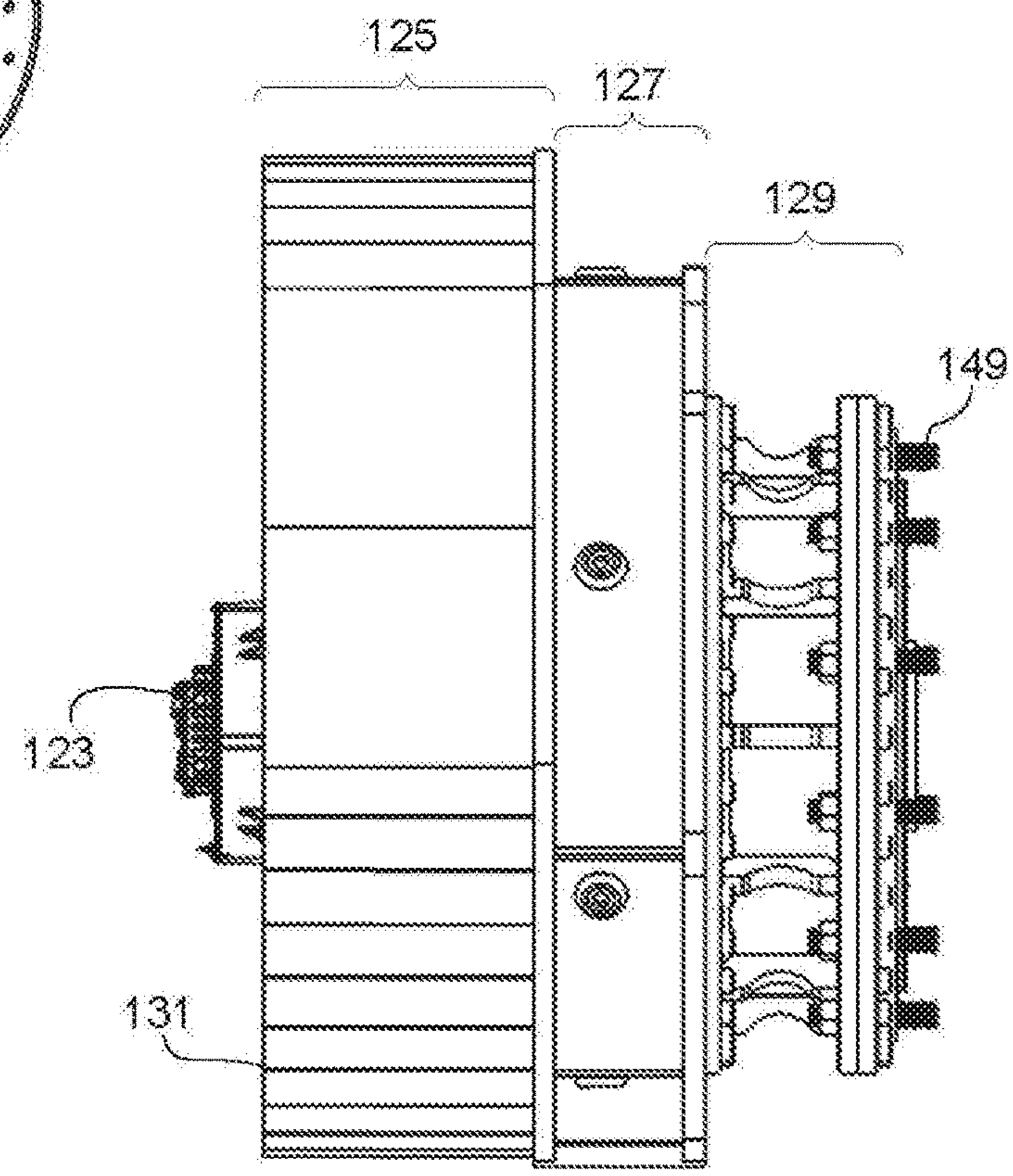

FIG. 7

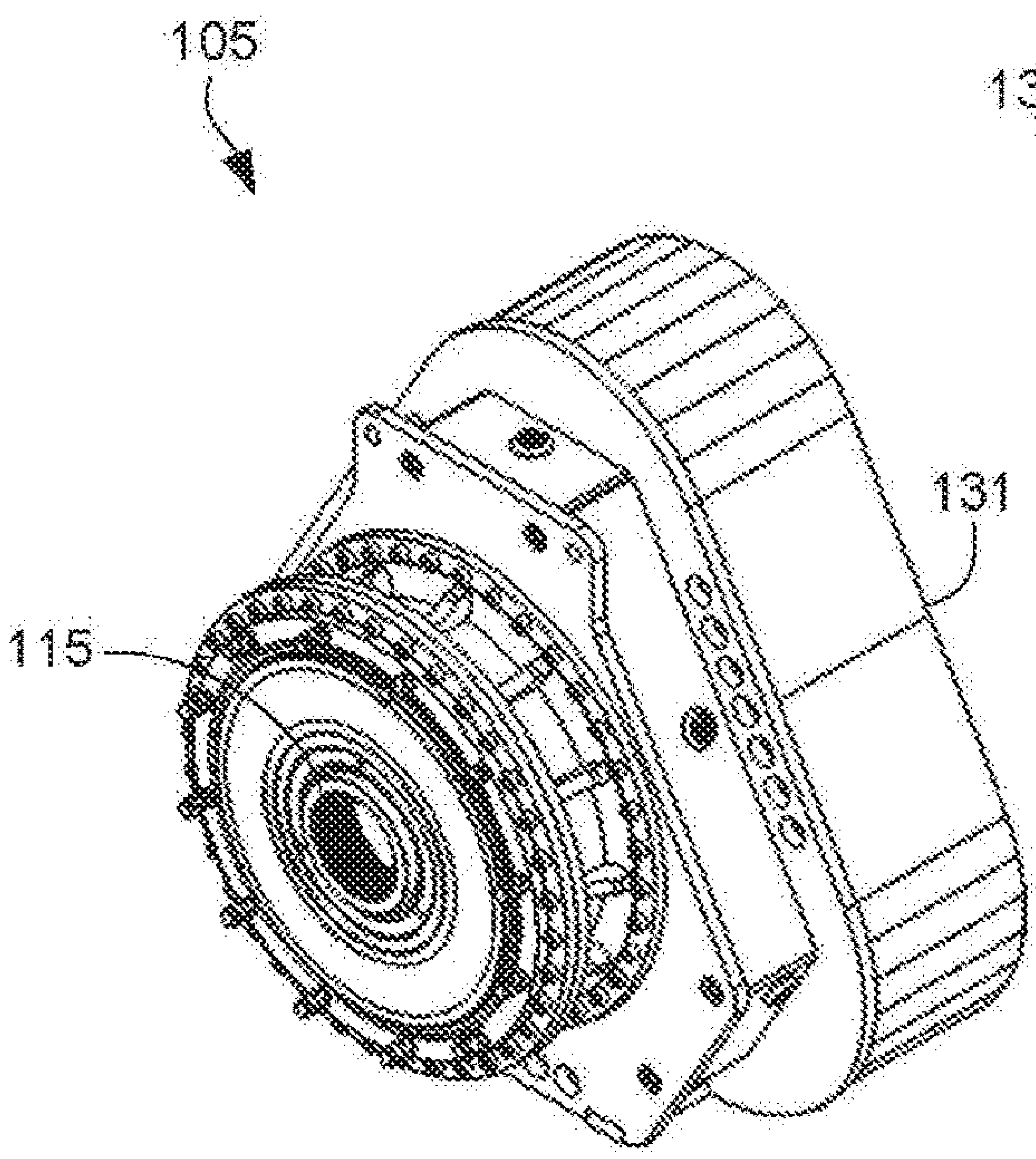

FIG. 8

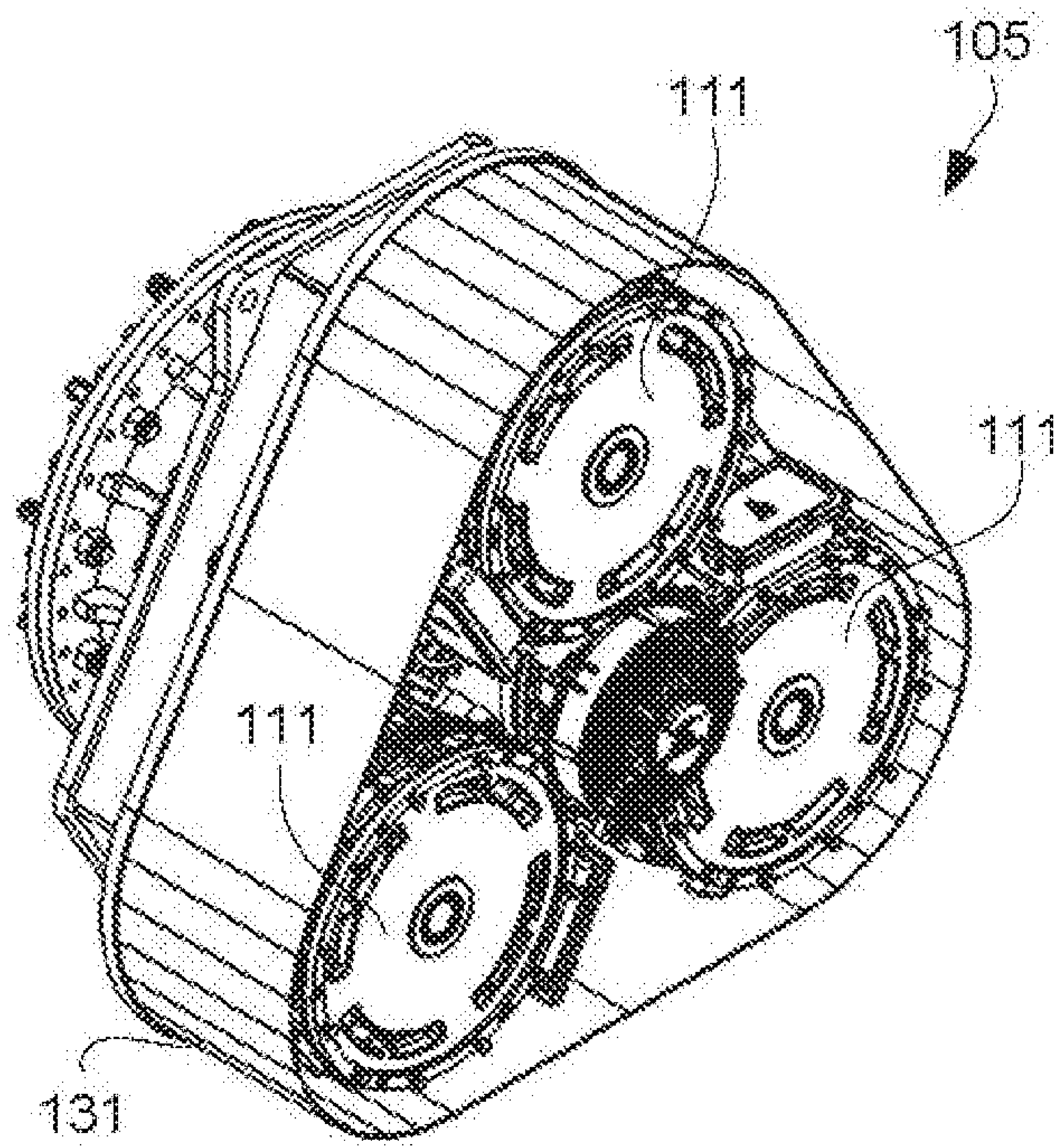

FIG. 9

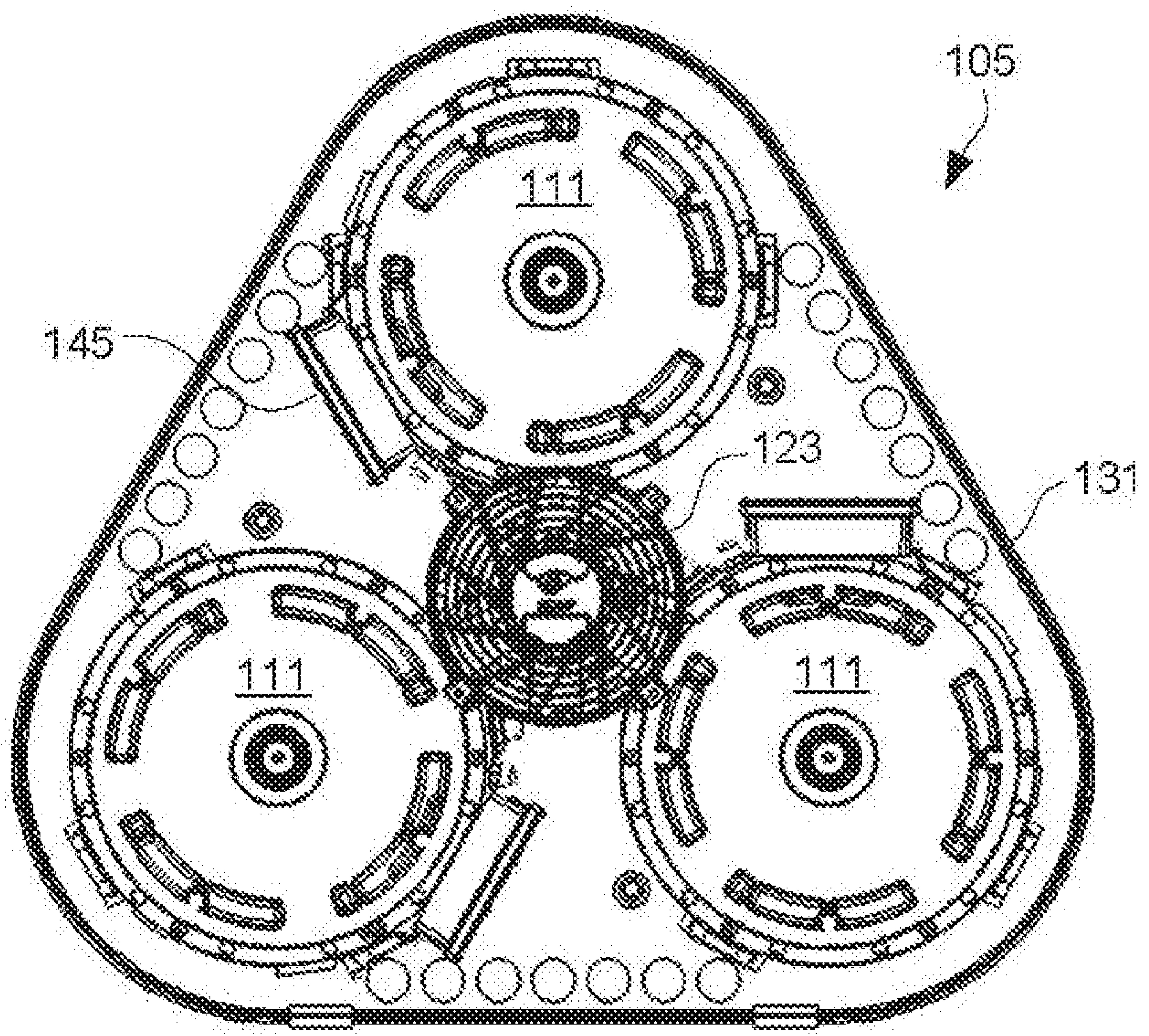

FIG. 10

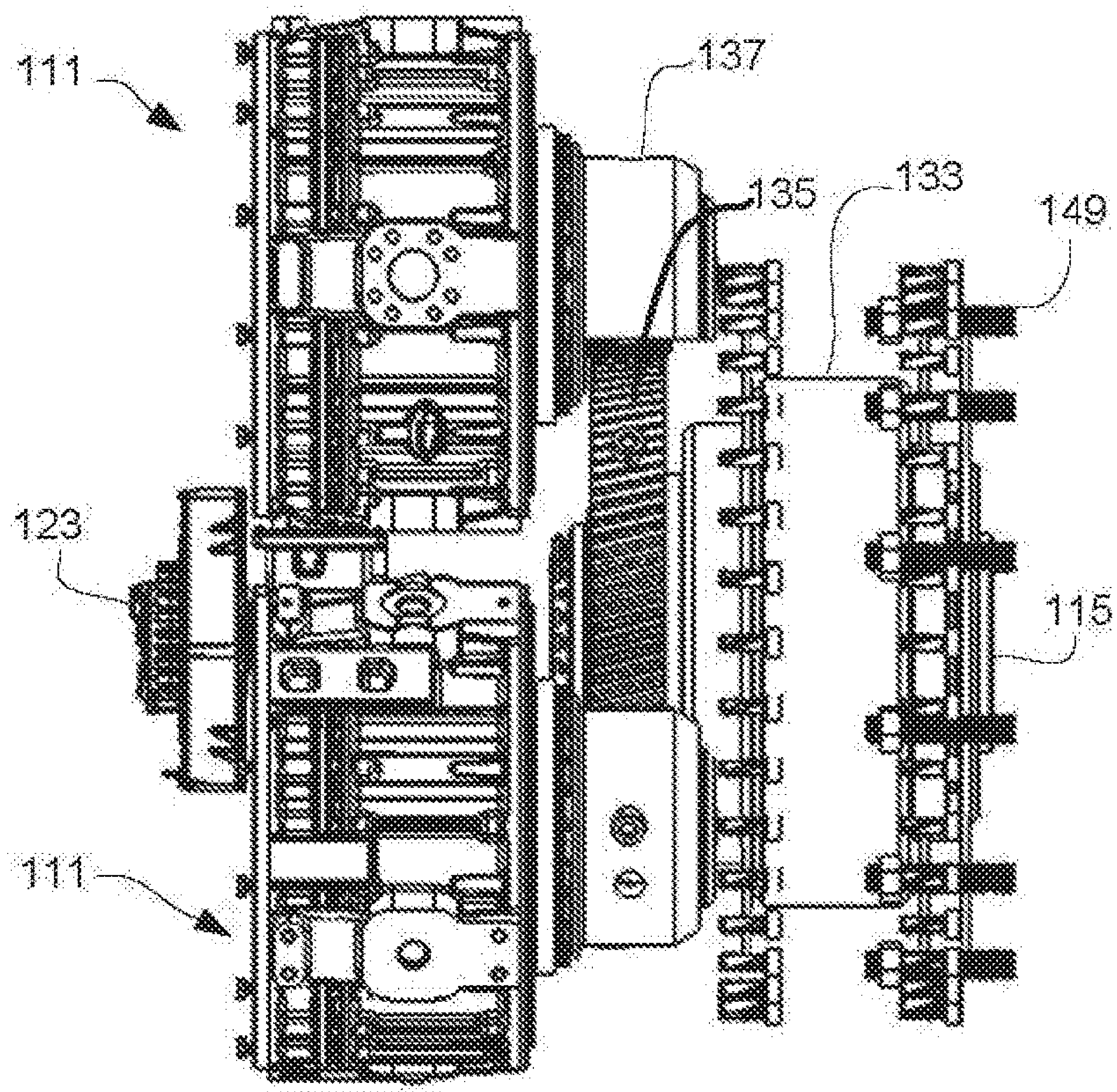

FIG. 11

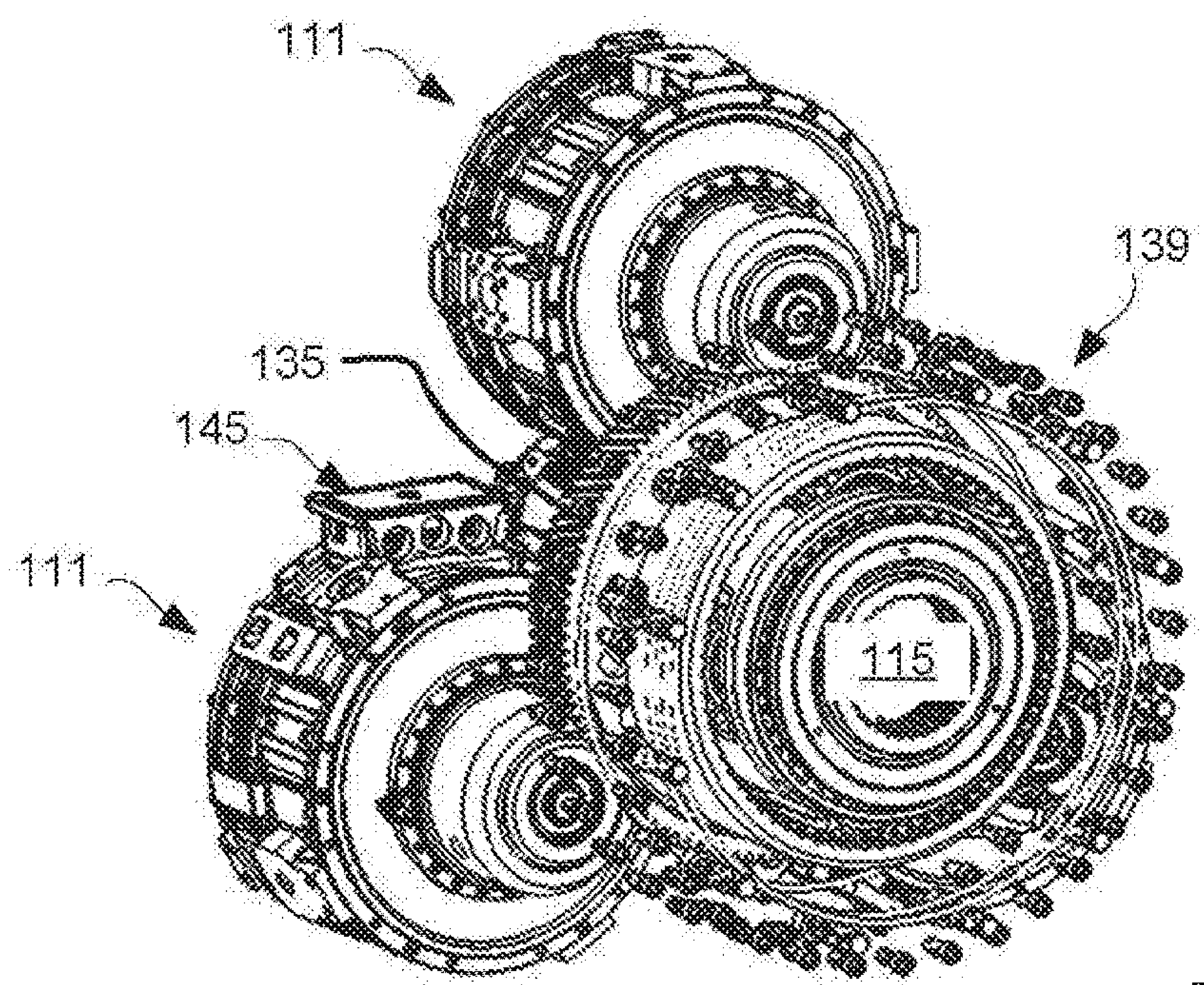

FIG. 12

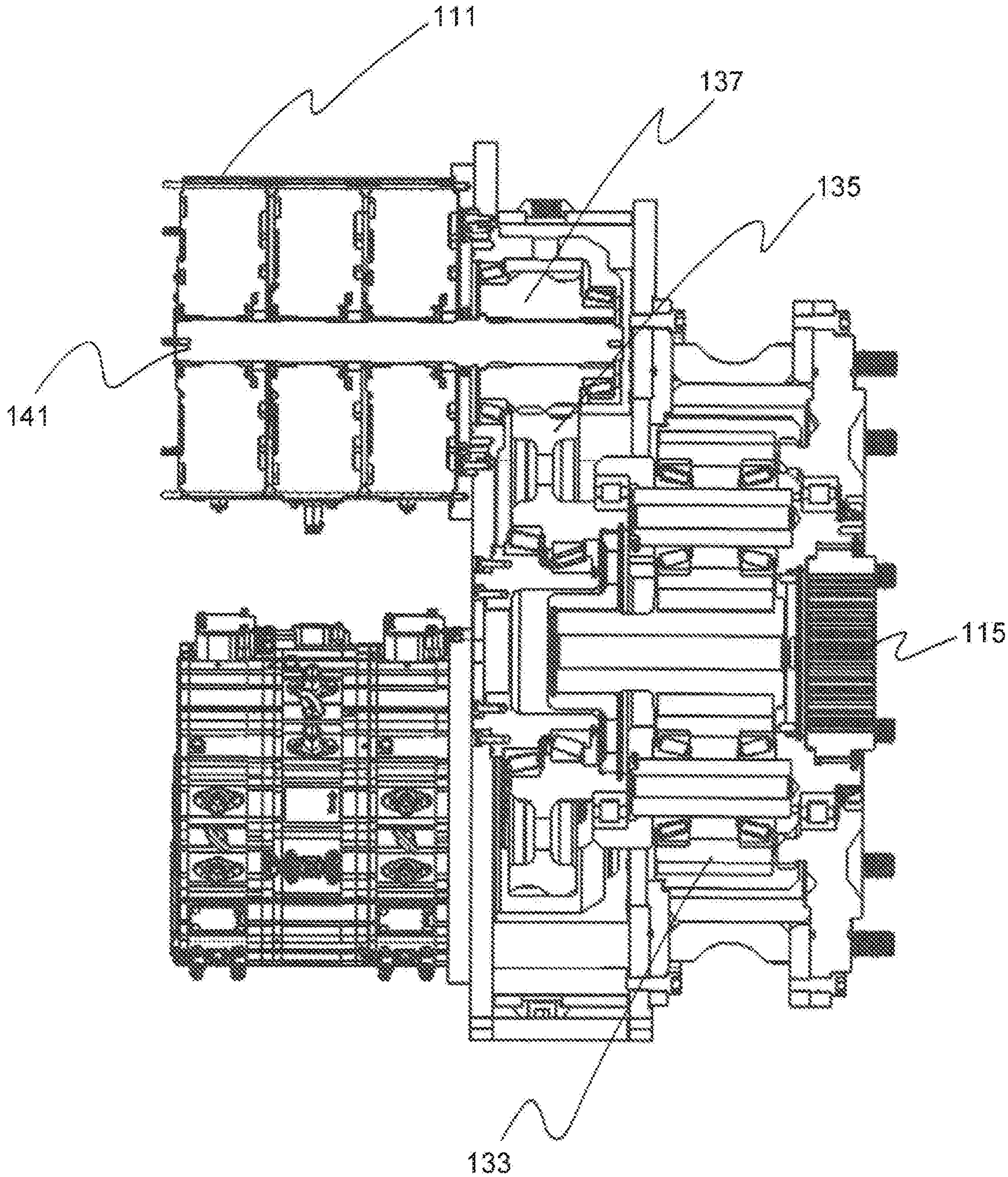

FIG. 13

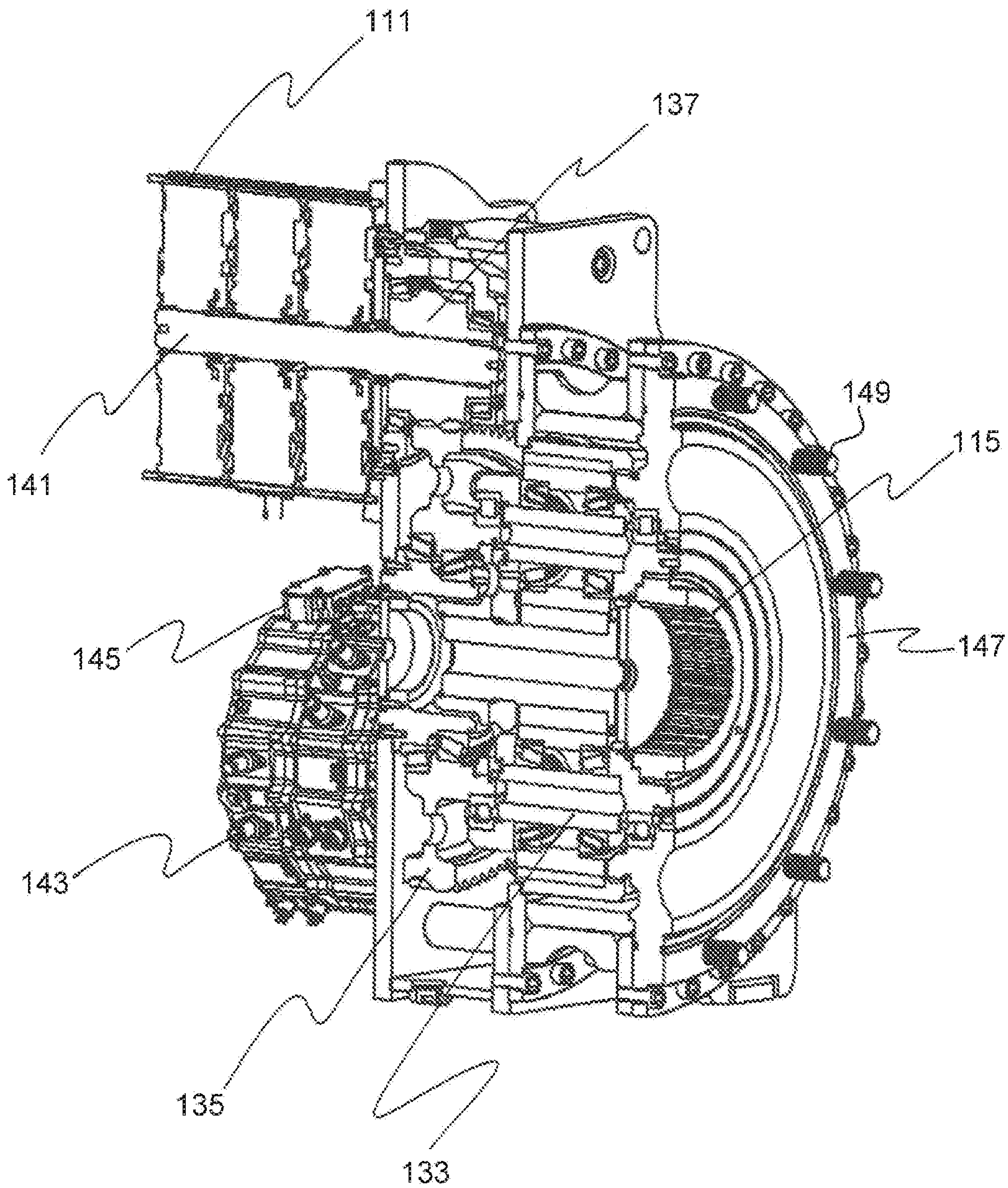

FIG. 14

Example: Tick Over

Motor #	Left Side	Right Side
1	On	On
2	Off	Off
3	Off	Off
4	Off	Off
5	Off	Off
6	Off	Off
7	Off	Off
8	Off	Off
9	Off	Off
10	Off	Off
11	Off	Off
12	Off	Off
13	Off	Off
14	Off	Off

FIG. 15

Example: 50% Required

Motor #	Left Side	Right Side
1	Off	Off
2	On	On
3	Off	Off
4	On	On
5	Off	Off
6	On	On
7	Off	Off
8	On	On
9	Off	Off
10	On	On
11	Off	Off
12	On	On
13	Off	Off
14	On	On

FIG. 16

Example: 100% Required

Motor #	Left Side	Right Side
1	On	On
2	On	On
3	On	On
4	On	On
5	On	On
6	On	On
7	On	On
8	On	On
9	On	On
10	On	On
11	On	On
12	On	On
13	On	On
14	On	On

FIG. 17

Example: 70% Required

Motor #	Left Side	Right Side
1	Off	Off
2	On	On
3	On	On
4	On	On
5	Off	Off
6	On	On
7	On	On
8	On	On
9	Off	Off
10	On	On
11	On	On
12	On	On
13	Off	Off
14	On	On

FIG. 18

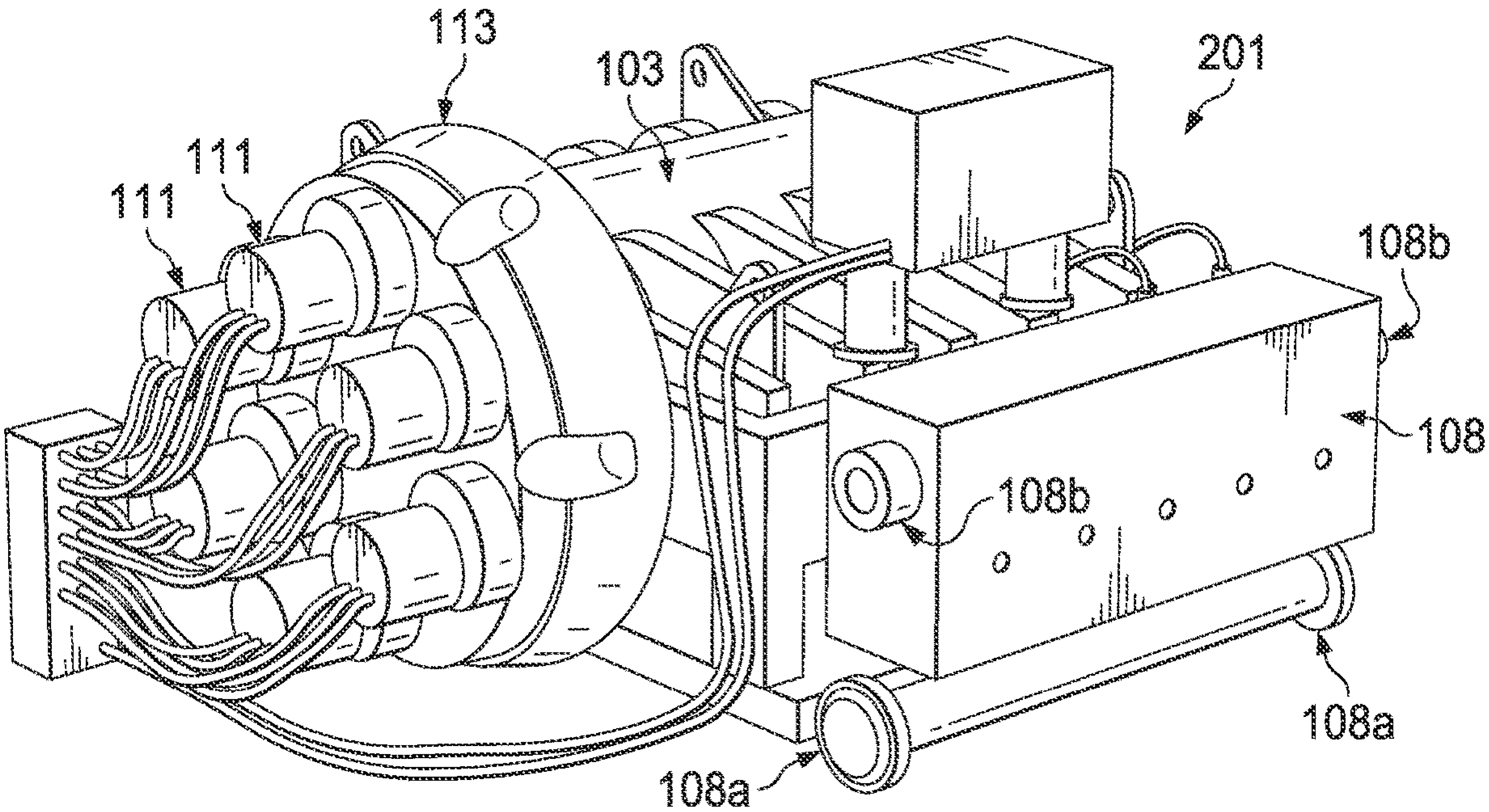
113
103
201
111
111
108b
108
108b
108a
108a

FIG. 19

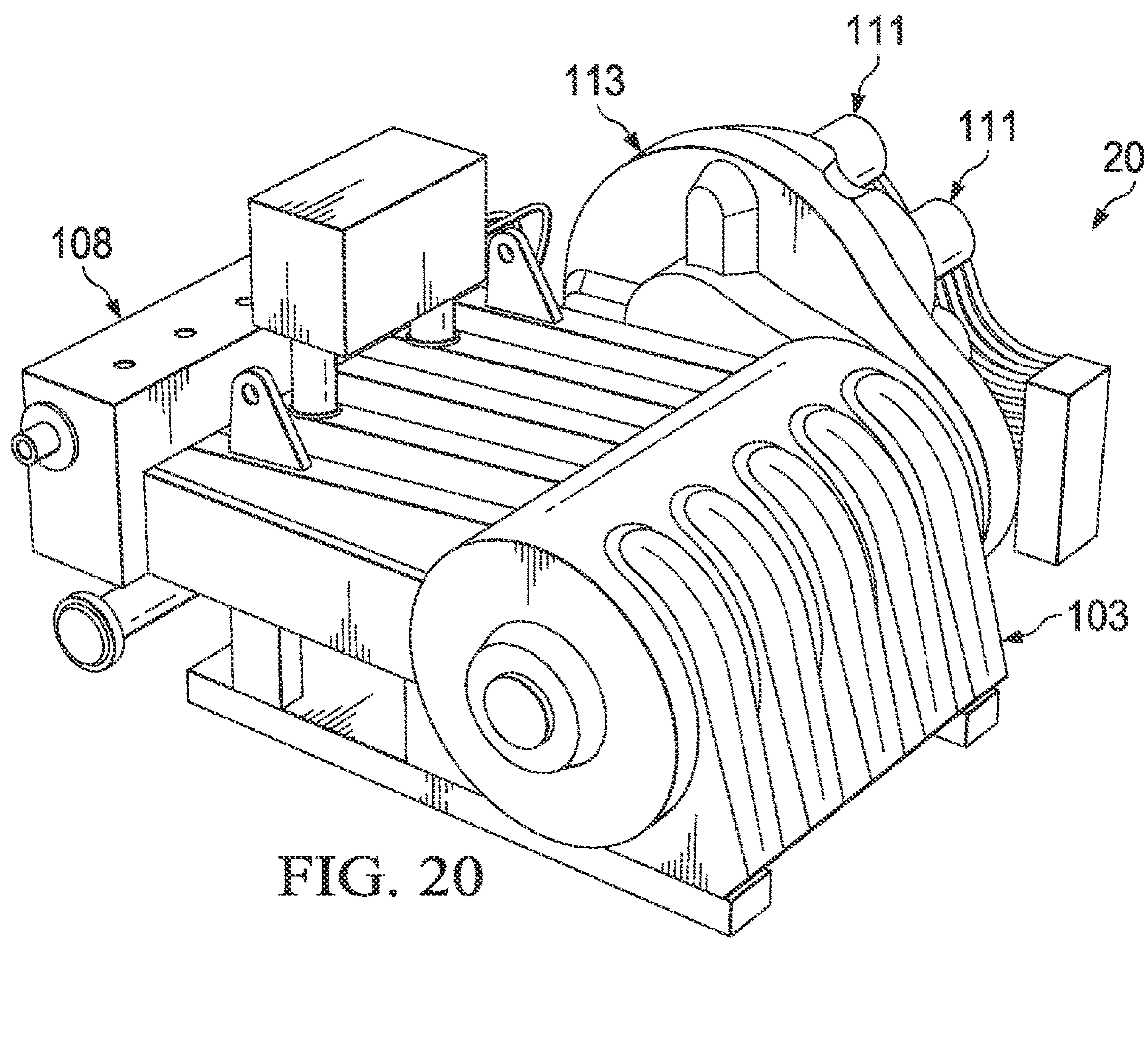
111
113
111
201
108
103

FIG. 20

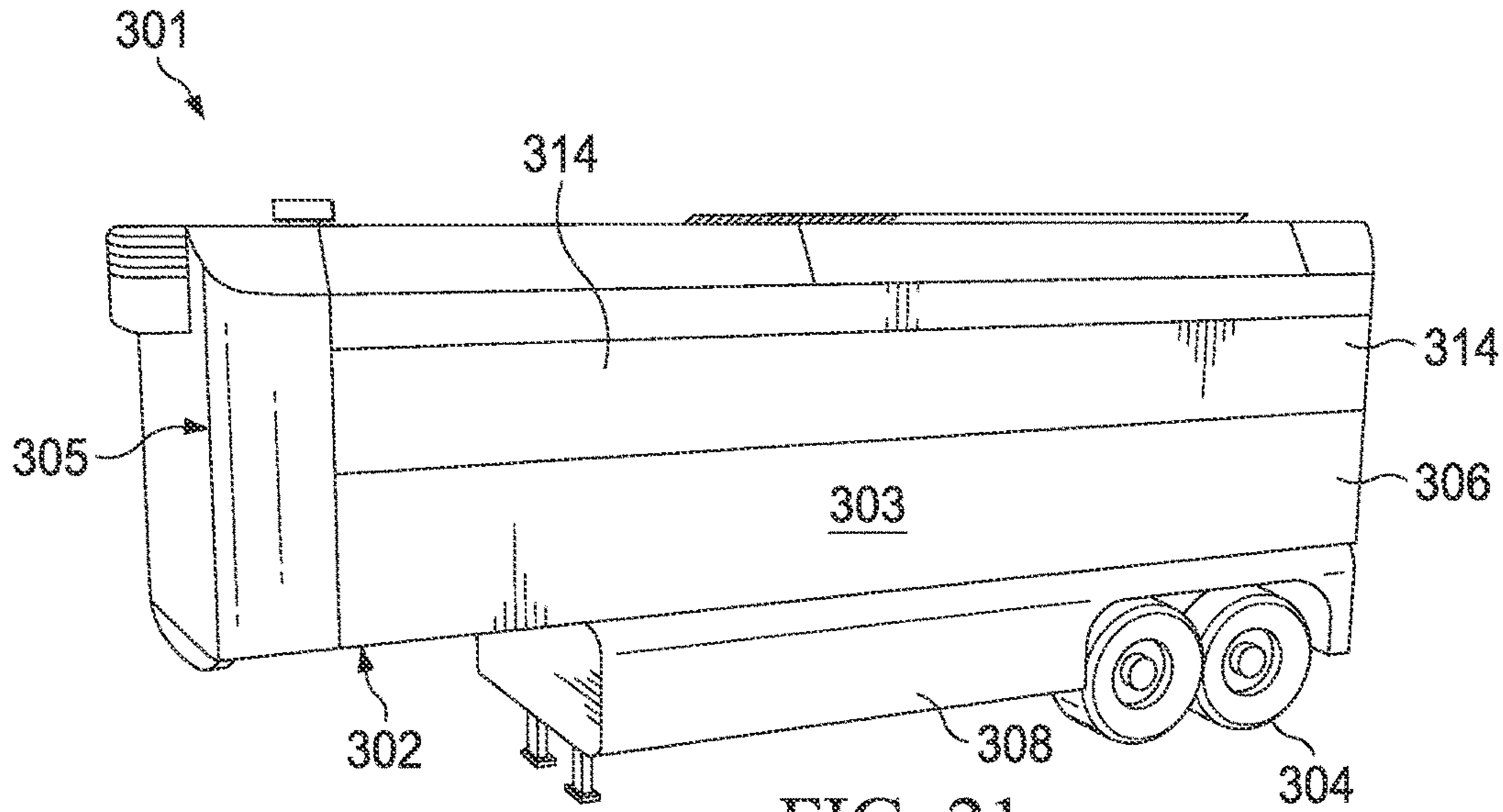
301
314
314
305
306
303
302
308
304

FIG. 21

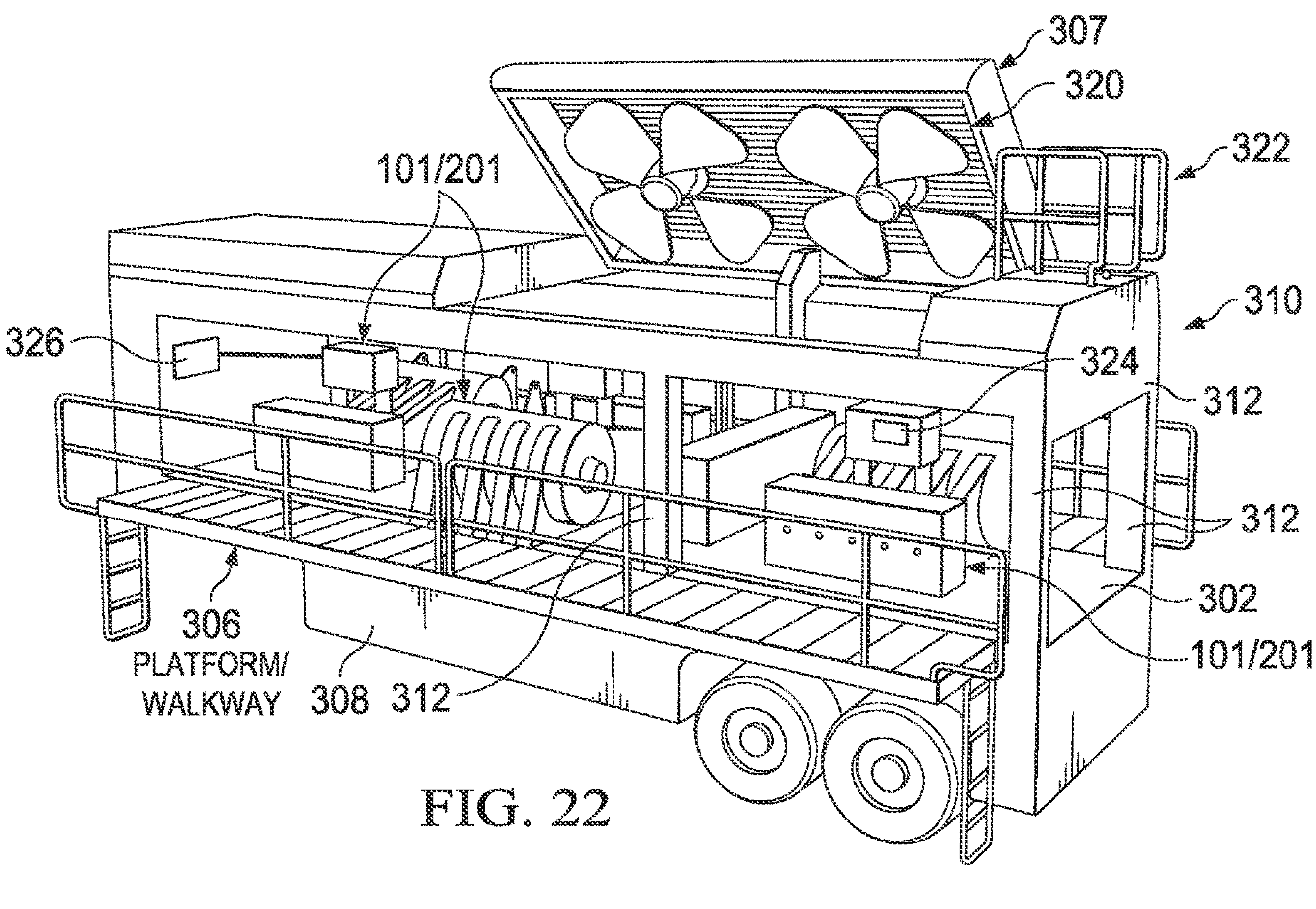
307
320
322
101/201
310
326
324
312
312
306
PLATFORM/
WALKWAY
302
101/201
308
312

FIG. 22

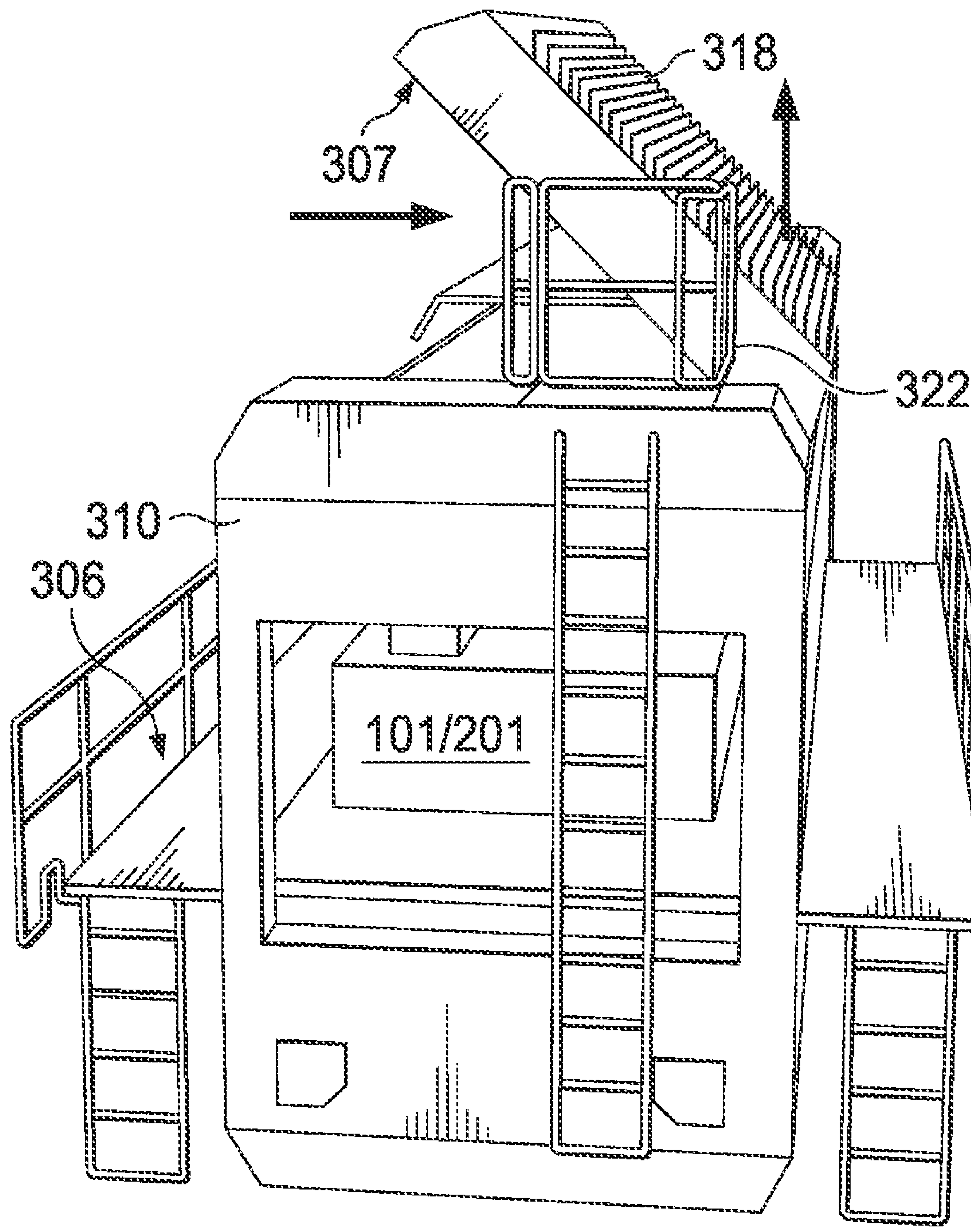

FIG. 23

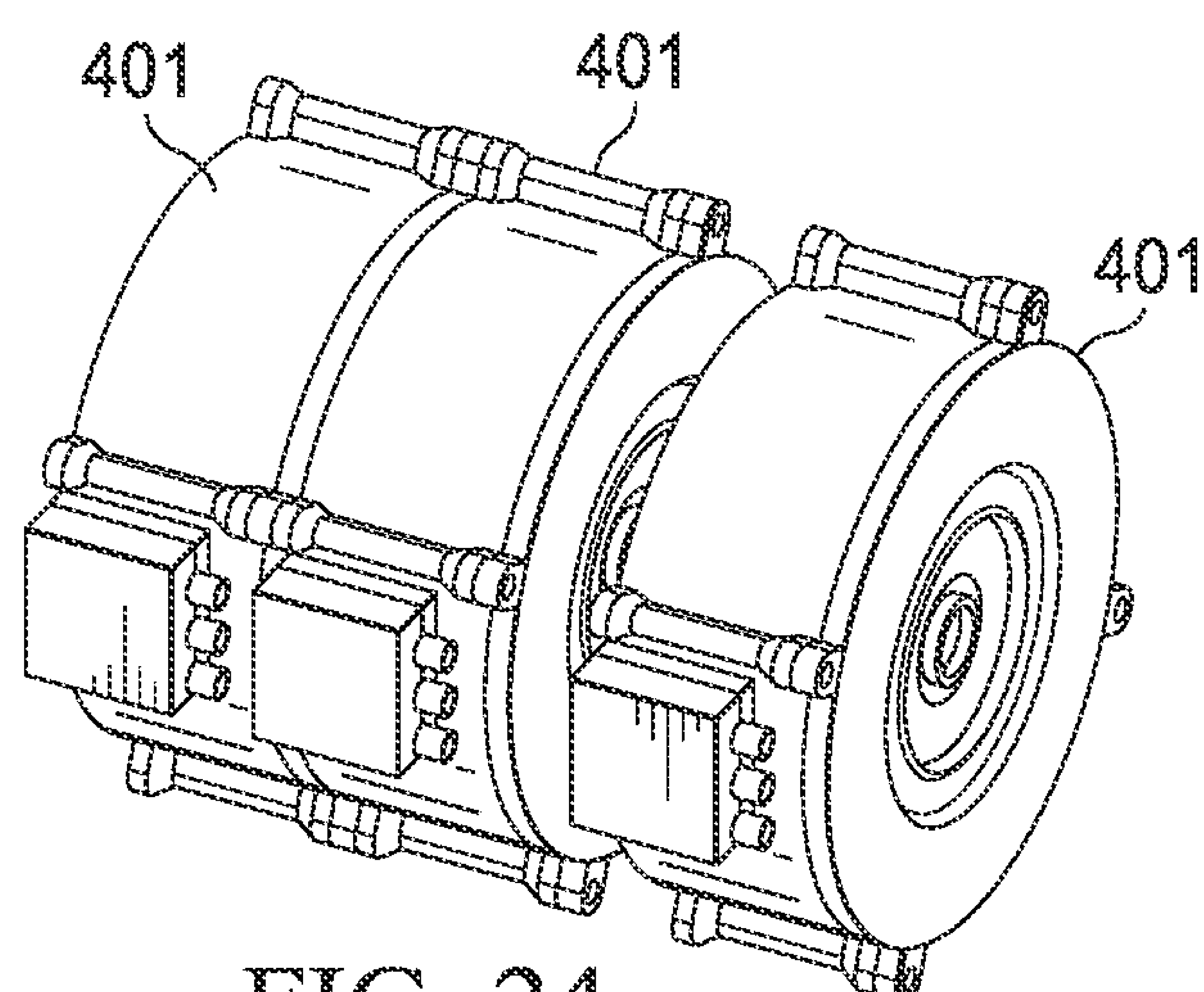

FIG. 24

ELECTRIC DRIVE PUMP FOR WELL STIMULATION

CROSS REFERENCE TO RELATED APPLICATION(S)

This application is a U.S. national stage patent application of International Patent Application No. PCT/US2019/027702, filed on Apr. 16, 2019, which claims priority to U.S. Provisional Application No. 62/658,139 filed Apr. 16, 2018, entitled "Electric Drive Pump for Well Stimulation" and International Patent Application PCT/US2018/052755 filed Sep. 25, 2018, entitled "Electric Drive Pump for Well Stimulation." The disclosure of each of these applications is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

The present application relates generally to hydraulic fracturing in oil and gas wells, and in particular to an electric drive pump used to drive a fluid end for the pumping of a fracturing fluid into a well.

BACKGROUND

It is difficult to economically produce hydrocarbons from low permeability reservoir rocks. Oil and gas production rates are often boosted by hydraulic fracturing, a technique that increases rock permeability by opening channels through which hydrocarbons can flow to recovery wells. Hydraulic fracturing has been used for decades to stimulate production from conventional oil and gas wells. The practice consists of pumping fluid into a wellbore at high pressure (sometimes as high as 50,000 PSI). Inside the wellbore, large quantities of proppants are carried in suspension by the fracture fluid into the fractures. When the fluid enters the formation, it fractures, or creates fissures, in the formation. Water, as well as other fluids, and some solid proppants, are then pumped into the fissures to stimulate the release of oil and gas from the formation. When the pressure is released, the fractures partially close on the proppants, leaving channels for oil and gas to flow.

Fracturing rock in a formation requires that the fracture fluid be pumped into the well bore at very high pressure. This pumping is typically performed by large diesel-powered pumps in communication with one or more fluid ends. These specialized pumps are used to power the operation of the fluid end to deliver fracture fluids at sufficiently high rates and pressures to complete a hydraulic fracturing procedure or "frac job." Such pumps are able to pump fracturing fluid into a well bore at a high enough pressure to crack the formation, but they also have drawbacks. For example, the diesel pumps are very heavy, and thus must be moved on heavy duty trailers making transport of the pumps between oilfield sites expensive and inefficient. In addition, the diesel engines required to drive the pumps require a relatively high level of expensive maintenance. Furthermore, the cost of diesel fuel is much higher than in the past, meaning that the cost of running the pumps has increased.

To avoid the disadvantages of diesel-powered pumps, some have moved to another option, such as electrically powered pumps. The electric frac pump configurations available now are largely comprised of existing mechanical units that are integrated into an electric system. This practice, however, can limit an operation's efficiency and performance.

Operators have at least two alternatives to choose from when in pursuit of a clean, electric power end pump. The first option offers a dual-motor configuration coupled with up to two triplex pumps. This large, industrial-sized, and air-cooled system can be capable of 3600-4500 hydraulic horsepower (HHP). The second option is a single-motor configuration. The centrally located motor is connected by two quintuplex pumps via a through-spindle design. This larger unit is also air-cooled, and is capable of 6000 HHP. Existing electric configurations experience inefficiencies in certain key areas. Contemporary offerings for electric frac configurations are composed of existing components from mechanical systems that are repurposed for electric applications. These components were not specifically built for electric systems. Consequently, effective horsepower is decreased due to design conflicts introducing hydraulic and mechanical resistance, as well as accelerated wear cycles as a result of violent harmonics and misalignments in provisional electric systems.

The inefficiencies do not end there: air-cooling solutions often leave something to be desired, as they are not capable of regulating the temperatures the motors generate, especially in environments where heat is a special concern. This leads to motors running hotter, and therefore, far less efficiently, which reduces the effective hydraulic horsepower of the entire operation. The inability to regulate running temperatures can also lead to premature failure.

There are other concerns regarding the integration of existing mechanical components and electrics, such as the optimization of the ratios used by power end reduction gears. Electric motors are often mistakenly considered to produce the same results at any RPM. Even though they have flatter and more consistent torque and power curves than internal combustion solutions, this is not entirely true. Electric motors do perform best within a certain RPM range, and contemporary offerings have not taken full advantage of the optimization that understanding provides. Reduction gear ratios that were not chosen for use in a specific electrical application, expose motors that drive them to possible premature failure, whether it be from spinning outside of the optimal range, or introducing harmonic imbalances and damaging the powertrain as a whole.

Although great strides have been made with respect to the power end of a fracturing pump system, there clearly is room left for improvement in electric drive pump fracing systems.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present disclosure and its features and advantages, reference is now made to the following description, taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a schematic illustration of an electric drive pump system according to an embodiment of the present application;

FIG. **2** is a front perspective view of an electric drive pump in the electric drive pump system of FIG. **1**;

FIG. **3** is a rear perspective view of the electric drive pump of FIG. **2**;

FIG. **4** is a side view of the electric drive pump of FIG. **2**;

FIG. **5** is a rear view of the electric drive pump of FIG. **2**;

FIG. **6** is a front perspective view of a transmission assembly in the electric drive pump of FIG. **2**;

FIG. **7** is a side view of the transmission assembly of FIG. **6**;

FIG. **8** is a rear perspective view of the transmission assembly of FIG. **6**;

FIG. **9** is an alternate front perspective view of the transmission assembly of FIG. **6**;

FIG. **10** is a front view of the transmission assembly of FIG. **9**;

FIG. **11** is an interior side view of the transmission assembly of FIG. **9**;

FIG. **12** is a rear perspective view of the transmission assembly of FIG. **11**;

FIG. **13** is a side section view of the transmission assembly of FIG. **12**;

FIG. **14** is a rear perspective view of the transmission assembly of FIG. **13**;

FIGS. **15-18** are charts of the operative functioning of the electric motors in various different power demand conditions;

FIGS. **19** and **20** are perspective view of an exemplary electric drive pump system of FIG. **1**;

FIGS. **21-23** are perspective views of a trailer system for transportation and operation of the electric drive pump of FIGS. **1**, **2**, **19** and **20**; and

FIG. **24** is a perspective view of an alternate embodiment of the electric motors, which may be employed by the electric drive pump systems of FIGS. **1**, **2**, **19** and **20**.

DETAILED DESCRIPTION

It is an object of the present application to provide an electric drive pump system for use in well stimulation. The electric drive pump system is configured to provide a plurality of individual motors in selective configurations that work together to provide power to a power end. The motors are arranged around a gearbox which is used to convert the rotary motion of the electric motors into linear motion for operation of the plungers in the fluid ends. The system includes a transmission assembly that is composed of the gearbox and the plurality of motors. The transmission assembly is detachable from any power end, and is operable with legacy power ends.

It is a further object of the present application to include a temperature regulation system that is configured to provide means of regulating the temperature of the components within the system. The temperature regulation system can be configured to provide both a heating effect and a cooling effect depending on configurations.

Another object is to provide a control module for the monitoring and regulation of the various components. The control module may use any number of sensors to monitor operations. The motors may be regulated in their performance as well as the temperature regulation system. Communication to and from the control module may occur through wireless and/or wired means. Any number of input/output interfaces may be included to input and receive parameters and instructions.

Ultimately the invention may take many embodiments beyond the exact depiction provided herein. This system overcomes the disadvantages inherent in the prior art.

The more important features of the system have thus been outlined in order that the more detailed description that follows may be better understood and to ensure that the present contribution to the art is appreciated. Additional features of the system will be described hereinafter and will form the subject matter of the claims that follow.

Many objects of the present system will appear from the following description and appended claims, reference being made to the accompanying drawings forming a part of this specification wherein like reference characters designate corresponding parts in the several views.

Before explaining at least one embodiment of the system in detail, it is to be understood that the system is not limited in its application to the details of construction and the arrangements of the components set forth in the following description or illustrated in the drawings. The system is capable of other embodiments and of being practiced and carried out in various ways. Also it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting.

As such, those skilled in the art will appreciate that the conception, upon which this disclosure is based, may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the various purposes of the present system. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present system.

Illustrative embodiments of the preferred embodiment are described below. In the interest of clarity, not all features of an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developer's specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

In the specification, reference may be made to the spatial relationships between various components and to the spatial orientation of various aspects of components as the devices are depicted in the attached drawings. However, as will be recognized by those skilled in the art after a complete reading of the present application, the devices, members, apparatuses, etc. described herein may be positioned in any desired orientation. Thus, the use of terms to describe a spatial relationship between various components or to describe the spatial orientation of aspects of such components should be understood to describe a relative relationship between the components or a spatial orientation of aspects of such components, respectively, as the assembly described herein may be oriented in any desired direction.

The system in accordance with the present application overcomes one or more problems commonly associated with conventional pumps used to stimulate a well. The electric drive pump system of the present application is configured to incorporate a plurality of electric motors to the power end or pump portion of a pump system. The motors are configured to operate either collectively or independently to vary the power supplied to the power end. The electric motors may operate in any combined manner and may operate in any sequential order. By including smaller motors, the motors are more easily obtained in the market, precise power requirements may be met smoothly, and overall power consumption may be minimized. Additionally, the electric drive pump system of the present application allows end-users to almost entirely eliminate hydrocarbon emissions by using clean-burning well gas turbines or local industrial power sources to fuel their operations. Noise pollution is also reduced by the removal of some of the loudest equipment on the pad, and electric configurations allow for cooling solutions that can be controlled to reduce or redirect most auditory nuisances. The electric drive pump system also has a smaller footprint on-pad than conventional pump systems. Maintenance is simplified to a considerable degree, since heavy, cumbersome mechanical power units are replaced with smaller, less complex electrical power units. These and other unique features of the device are discussed below and illustrated in the accompanying drawings.

The system will be understood, both as to its structure and operation, from the accompanying drawings, taken in conjunction with the accompanying description. Several embodiments of the assembly may be presented herein. It should be understood that various components, parts, and features of the different embodiments may be combined together and/or interchanged with one another, all of which are within the scope of the present application, even though not all variations and particular embodiments are shown in the drawings. It should also be understood that the mixing and matching of features, elements, and/or functions between various embodiments is expressly contemplated herein so that one of ordinary skill in the art would appreciate from this disclosure that the features, elements, and/or functions of one embodiment may be incorporated into another embodiment as appropriate, unless otherwise described.

The system of the present application is illustrated in the associated drawings. The assembly includes a portable base member that can roll along the ground. The base member defines an interior volume used for storage of various members and portions of the assembly. It also includes an elevating platform in communication with the base member. The elevating platform operates between a lowered position and an elevated position. The assembly is stabilized by one or more jacks and a hitch attachment assembly configured to secure the base member to the neighboring vehicle. Additional features and functions of the device are illustrated and discussed below.

Referring now to the Figures wherein like reference characters identify corresponding or similar elements in form and function throughout the several views. The following Figures describe the assembly of the present application and its associated features. With reference now to the Figures, an embodiment of the electric drive pump system is herein described. It should be noted that the articles “a”, “an”, and “the”, as used in this specification, include plural referents unless the content clearly dictates otherwise.

Referring to FIG. **1** in the drawings, a schematic of an electric drive pump system **101** for well stimulation through a power end is provided. The electric drive pump system **101** includes a power end **103**, a transmission assembly **105**, a control module **107** and a temperature regulation assembly **109**. Power end **103** is configured to convert, via a crankshaft **104**, the rotational/rotary motion generated through transmission assembly **105** into a linear motion for operation of plungers **106** within one or more fluid ends **108**. Power end **103** may have operate with any number of fluid ends **108** and may be constructed from a casting or fabricated from one or more materials. In one or more embodiments, the crank shaft **104** extends between a first end **104***a* and a second end **104***b* with a transmission assembly **105** mounted on each end **104***a*, **104***b* of crankshaft **104** in order to balance torque applied to crankshaft **104** and maximize power input.

Transmission assembly **105** is releasably mounted to power end **103**, and includes at least one, and in some embodiments, a plurality of electric motors **111** and a gearbox **113** in communication with the one or more electric motors **111**. In some embodiments, the one or more electric motors **111** may comprise axial flux motors, as described in greater detail below, because of their high power density and their relatively short axial length compared to traditional radial flux motors, thereby allowing the overall drive pump system to be self-contained on a single skid or trailer (see FIG. **21**), a desirable benefit at a hydrocarbon drilling and production site where space is at a premium. In one or more embodiments, a transmission assembly **105** is mounted on each end of crankshaft **104** and each transmission assembly **105** includes at least one axial flux motor **111**. In some embodiments, each transmission assembly **105** includes three spaced apart axial flux motors **111**. As discussed below, one feature of axial flux motors is that they can be stacked, as shown in FIG. **1**. Thus, in some embodiments, each transmission includes one or more axial motor stacks having two or more axial motors **111** engaged with one another so as to be “stacked” along their primary axis so as to be coaxial. In any event, the gearbox **113** includes a plurality of gears for transferring rotational energy from the one or more electric motors **111** to the power end **103**. Transmission assembly **105** may also include an output spline **115** in communication with gearbox **113**. Output spline **115** (FIG. **8**) is configured to transfer rotational energy from gearbox **113** to power end **103**, e.g. to a crank shaft **104** within the power end **103**. In general, transmission assembly **105** is configured to hold the drive system (motors **111** and gearing) along with cooling components and sensors.

System **101** also includes control module **107** configured to regulate performance of transmission assembly, **105**, particularly where a plurality of electric motors **111** are employed. Electrical power is provided to motors **111** which in turn are used to induce a torque of selected power to rotate gears within gearbox **113**. Control module **107** is used to monitor the performance of each motor **111** and control selected functions, such as power output, speed, on/off, unit temperature, and so forth. It is understood that these are exemplary in nature and do not form an exhaustive listing of performance characteristics or functions that module **107** may regulate with respect to motors **111** or system **101**. Through control module **107**, operation of motors **111** can be done simultaneously as a group at a selected power level and/or independently wherein each motor **111** is independent of the operation of other motors **111** with respect to at least power output and runtime. Use of a plurality of motors **111** allows for simplification of maintenance as one or more motors **111** may be turned off for maintenance while others remain on to maintain operation of power end **103**.

Although axial flux or “pancake” motors are shown, it is understood that many different types of motors **111** exist and are possible in other embodiments. For example, motors **111** may be AC or DC, single or multiple wound, brushed or brushless, direct drive, servo or stepper motors. Another option is that motors **111** are rare earth magnet motors which have increased power density. Motors **111** may be powered via battery stacks or direct feed from a main power grid. Additionally, motors **111** may be powered off of waste gas from the sites. Ideally a DC power system is preferred.

As seen in FIG. **1**, a plurality of transmission assemblies **105** may be coupled to drive power end **103**. Motors **111** can be configured to operate in a clock-wise (CW) direction or a counter clock-wise (CCW) direction so as to collectively rotate in the same direction relative to power end **103**. Also seen in FIG. **1**, motors may be arranged in any manner within transmission assembly **105**. One or more motor **111** may be in direct communication with gearing in gearbox **113**. Subsequent or additional motors **111** used may be stacked behind an adjacent motor **111**. In stacked configurations, the stacked motors **111** work together in a prescribed fashion according to control module **107** to apply power to gearbox **113** at a single location.

Temperature regulation assembly **109** is configured to regulate the temperature levels of various components and members of system **101**. For example, temperature regulation assembly **109** is configured to regulate the temperature of power end **103** and/or transmission assembly **105**. Module **107** is configured to operatively regulate performance of assembly **109**. One or more sensors are located throughout system **101** and communicate temperature readings back to module **107** and/or assembly **109**. Assembly **109** includes a radiator and a cooling fan and uses any type of working medium (i.e. fluid) to facilitate temperature regulation. Assembly **109** may use an oil based fluid or a water based fluid as the working medium.

Additionally, assembly **109** is configured to provide both a cooling effect and a heating effect. For example, to optimize the performance of system **101**, assembly **109** can be used to heat critical components within system **101** to a stable operating temperature before actuation of the system as a whole. Assembly **109** then may switch to a cooling mode to cool various components while in operation so as to keep the working medium temperature optimized.

FIGS. **2-14** are provided to show an exemplary embodiment of system **101**. This embodiment is not limited to the physical characteristics so depicted but can extend to other embodiments that are considered within the same functional scope and spirit of the present system.

Referring now also to FIGS. **2-5** in the drawings, views of electric drive pump system **101** is illustrated. System **101** is shown in a front perspective view in FIG. **2** and a rear perspective view in FIG. **3**. Power end **103** is situated between two transmission assemblies **103**. Temperature regulation assembly **109** is shown adjacent power end **103**. Power end **103** and temperature regulation assembly **109** are resting on a platform **117**. Platform **117** is configured to elevate system **101** off the ground and provide for the overall stability of system **101**. Platform **117** is configured to enable mobility of system **101**. System **101** may be lifted by engaging platform **117** in one method. Other methods may involve pushing, pulling, or sliding for example. Platform **117** may be a skid, trailer, operate off of wheels, or consist of any mobile type of device. As seen in the Figures, a plurality of fasteners are used to couple transmission assembly **105** to power end **103**. Assembly **105** is detachable and interchangeable. During servicing, a single assembly **105** may be removed and replaced in a simple manner to avoid down time of the system.

Temperature regulation assembly **109** is shown in more detail from the side view of FIG. **4** and the rear view of FIG. **5**. Assembly **109** includes a radiator **119** and a fan **121**. Radiator **119** may include one or more cores with each core having the ability to cool a working medium to produce a cooling effect. This effect can be provided to motors **111**, transmission assembly **105**, and power end **103**. Any type of working medium may be used to pass within the core of radiator **119**. It is understood that multiple cores may be used. They may be stacked together in any manner. Each of the plurality of cores may be either independent from one another or in fluid communication with each other. Independent cores permit for the use of different working mediums. Use of different mediums may assist in providing both heating and cooling via the same radiator. Fan **121** is configured to pass air onto radiator **119** so as to create an exchange of heat.

It is worth noting as well that in FIGS. **4** and **5** the use of a circulation fan **123** is also seen in communication with transmission assembly **105**. Fan **123** is configured to selectively pass air over motors **111** by having outside air (outside of transmission assembly **105**) enter and mix within assembly **105**. Fan **123** may work independent of assembly **109** or in conjunction therewith. Module **107** may be used to regulate fan **123**.

Referring now also to FIGS. **6-8** in the drawings, assorted views of transmission assembly **105** are illustrated. AS noted previously, assembly **105** is detachable from power end **103**. Transmission assembly **105** is depicted herein separated therefrom as a whole unit. Transmission assembly **105** is composed of a plurality of various components and assemblies working together to provide the transfer of rotational energy to power end **103**. As seen in the side view of FIG. **7**, transmission assembly **105** includes a motor portion **125**, a gear reduction assembly **127**, and a planetary assembly **129**. These general assemblies **125** and **127** are defined in their relative location in FIG. **7** and constitute gearbox **113**. In the case of motor portion **125**, transmission housing **131** is a cover that surrounds motors **111**. In FIG. **8**, output spline **115** is shown. As motors **111** rotate gearing in gearbox **113**, output spline **115** rotates and drives power end **103**.

Referring now also to FIGS. **9** and **10** in the drawings, an alternate front perspective view and front view of transmission assembly **109** is illustrated. In these Figures, a portion of housing **131** is removed for clarity and to permit a view of motors **111**. Motors **111** are arranged in a radial manner about output spline **115**. Fan **123** has been maintained for visual purposes.

Referring now also to FIGS. **11-14** in the drawings, assorted views of the gearing in transmission assembly **105** is illustrated. FIG. **11** is an interior side view of transmission assembly **105** without housing **131** and covers associated with gearbox **113** so as to show the gearing being used. Planetary system **133** (i.e. gears) are illustrated adjacent output spline **115**. A bull gear **135** is shown as being located between planetary system **133** and a spur gear arrangement **137**. Power from motors **111** pass to the spur gear **137**, to the bull gear, and then to the planetary system before being output through the output spline **115**. A rear perspective view is shown in FIG. **12** and is provided for perspective. The gear reduction **139** is shown in more clarity.

In particular with FIG. **13** in the drawings, a side section view of transmission assembly **105**, from FIG. **11**, is provided. In this view, each of the prior gearing is shown from the side and serves to enhance clarity in the gearing options. Planetary system **133** is understood to be suitable for any number of configurations. Output spline **115** connects transmission assembly **105** to a crank shaft in power end **103**. It is understood that this could also be facilitated through a key drive or flexible coupling arrangement. Motors **111** are shown in section view as well. A drive shaft **141** is shown passing through the central part of motors **111**. Each motor engages shaft **141**. Shaft **141** engages and contacts the spur gear **137**. Also of note is the stacking capability of motors **111**. As shown, three motors are stacked to one shaft **141**.

In particular with FIG. **14** in the drawings, a rear perspective view of FIG. **13** is shown for clarity. In this view, a liquid port **143** is made more visible on motor **111**. Assembly **109** is able to engage motors **111** through this port to provide a cooling/heating effect. Module **107** may communicate with motors **111** through a cable entrance point **145**. Additionally, a power source may also use entrance point **145** to provide power to run motors **111**. A coupling flange **147** is shown as well. This is used to facilitate mating between transmission assembly **105** and power end **103**.

Contact with power end **103** may occur along this flange. The fasteners **149** are used to secure assembly **105** in position.

Referring now also to FIGS. **15-18** in the drawings, charts of the operative functioning of the electric motors **111** are illustrated. As noted previously, motors **111** may operate as a collective whole or independent of one another. Motors **111** can be used in a continuous duty cycle or as a sequenced duty cycle to meet the requirement of the pumps output. Each chart includes a table showing fourteen motors **111** which may be associated with a left side and a right side (the number of motors is exemplary only). Under each side a label of "on" and "off" is provided. In FIG. **15**, an example of the operation of the motors **111** is provided wherein only a small amount of power is needed. In this condition, only motor #1 is turned on. The others remained off.

In FIG. **16**, a 50% output is required. To produce this amount, the even numbered motors **111** are operative while the odd numbered motors **111** are deactivated or turned off. In this case, 50% power is provided by operating half the motors **111** at full capacity. In FIG. **17**, 100% power is required and therefore all motors **111** are turned on. In FIG. **18**, 70% power is required. In this example, motors **1**, **5**, **9**, and **13** are off while the others are on. As seen from the exemplary charts of FIGS. **15-18**, the power supplied can be adjusted by changing the number of motors **111** turned on and the respective power output through each motor.

As alluded to above, it would appear that each motor **111** is configured to operate in full output mode only. It is understood that the system of the present application may permit the motors **111** to be run at various speeds or power outputs. This could allow all the motors **111** to operate for a 50% required output, where each motor **111** is producing only ½ its max output. An advantage of varied output motors **111** would be that potentially maintenance may be provided to selected motors **111** during operation of the fluid end without the need to completely shut down operations as other motors **111** may be set to compensate for the needed load conditions. Naturally, the motors **111** may interact and operate in any number of different manners.

Referring now to FIGS. **19** and **20**, perspective views of an alternate exemplary embodiment of an electric drive pump system **201** are provided. System **201** is similar in form and function to the embodiment of system **101** seen in FIGS. **1** and **2**. System **201** uses motors **111** located on at least one end of a power end **203** to drive a fluid end **108** generally having at least one fluid inlet **108*a*** and at least one fluid outlet **108*b***. In some embodiments, fluid end **108** may include a plurality of inlets **108*a*** and/or a plurality of outlets **108*b***. In some embodiments, fluid end **108** may include a plurality of inlets **108*a*** and at least two outlets **108*b***. In some embodiments, fluid end **108** may include at least two inlets **108*a*** and at least one outlet **108*b***. In the illustrated embodiment, only one end of power end **203** is equipped with an array of individual motors **111**. However, in other embodiments, each end of the power end **203** is equipped with an array of individual motors **111**. In any event, six motors are depicted although more or fewer may be used. The six motors **111** are arranged circumferentially about one or more gears (as seen in FIGS. **7** and **8**) or a gearbox **113**. The gears may be planetary gears or chain driven for example. In other embodiments, the motors **111** may be arranged in a direct drive configuration on a center line of a crank shaft **104** (FIG. **1**) in the power end **203**.

Referring now also to FIGS. **21-23** in the drawings, illustrations of a mobile or portable system **301** for use with electric drive pump systems **101** and **201** are provided. In one or more embodiments, mobile system **301** is a trailer system **301** as shown, and includes a platform **302** supported on a plurality of wheels **304**. In other embodiments, mobile system **301** may simply be a skid or platform **302** without wheels. In other embodiments, the platform **302** may be elevated above a ground surface by supports, jacks or other mechanisms. One or more electric drive pump systems **101/201** are coupled to the platform **302** surrounded by a frame **310**. The frame **310** includes a plurality of spaced apart support members **312**, which support enclosure panels **314** therebetween. As illustrated in FIG. **21**, the frame **310** and the enclosure panels **314** may be configured to substantially enclose the electric drive pump system(s) **101/201** within an enclosed trailer unit **303**. The trailer system **301** is thus configured to house and transport the one or more electric drive pump systems **101/201** on the trailer platform **302** in a fully enclosed and protected environment. The enclosed trailer unit **303** can be fully closed (FIG. **21**) and subsequently opened (FIG. **22**) to permit operation of the electric drive pump systems **101/201**. The enclosed configuration may facilitate transportation of the pump systems **101/201**, and the enclosed trailer unit **303** provides some concealment to the public about the contents within. To open the trailer unit **303**, the enclosure panels **314** may be moved or removed from frame **310** and trailer platform **302**.

Enclosed trailer unit **303** multiplies the benefits of electric drive pump system **101/201** components. The trailer system **301** was designed for fast, long-distance travel. The trailer platform **302** can be accessed via its ISO/SAE compliant walkway or platform system **306**, providing the crew with a safe, stable position from which they can perform routine maintenance on site. The platform system **306** is pivotally coupled to the trailer platform **302** to simplify storage and deployment. The platform system **306** operates as an enclosure panel **314** when pivoted upward toward the frame (FIG. **21**) and operates as a walkway when pivoted downward (FIG. **22**). Storage compartments **308** for maintenance items may be provided below the trailer platform **302** as well, negating the need for crews to transfer equipment across the pad. For example, the compartments **308** may be located directly beneath the equipment to be maintained, e.g., the electric drive pump system **101/201**. In some embodiments the trailer system **301** can also be configured with a full environment enclosure to create a safe workplace environment for crews even in extreme weather conditions. This may be achieved, e.g., with slide-out walkways **306** (not shown) which may be deployed with one or more enclosure panels **310** coupled thereto. Slide out walkways **306** and enclosure panels **314** allow the interior of unit **303** to remain climate controlled. These optimizations reduce non-pumping downtime and increase crew safety by making the entire trailer system **301** operable in any weather condition and equally accessible to any site.

The management of pump cooling is a critical operation in all applications, and trailer unit **303** provides a superior solution to achieve precise control. Coolant from electric drive pump systems **101/201** components are mutable to a top-mounted variable-angle radiator pack **307**, which is easy to reconfigure. The angle of the radiator pack **307** can be altered to increase cooling efficiency or reduce noise by controlling the turbulence of the circulating air through one or more vanes **318** (FIG. **23**). The radiator pack **307** may be pivotably coupled to the frame **310** and supportable in a plurality of distinct angular positions with respect to the frame **310**. The radiator's fans **320** are also capable of reverse drive, allowing the system to clear any debris from its radiative surfaces, thus maintaining maximum efficiency and ensuring stable temperatures. The radiator pack **307** can be easily accessed via the rear-mounted personnel access platform **322** for any necessary maintenance.

The design of trailer system **301** also houses a telematics suite. The telematics control unit **305** is capable of communication via satellite, Wi-Fi, Bluetooth, and GSM between the electric drive pump system **101/201** and a remote location with respect to the trailer system **301**. Edge computing monitors the telemetry from sensors **324** within all critical systems of electric drive pump systems **101/201**, allowing personnel to monitor performance and increase efficiency on and off site, while avoiding unnecessary costs in repairs and maintenance. Telematics control unit **305** may include one or more variable frequency drives (VFDs **326**) operably coupled to the to regulate the operation of the motors **111** (FIG. **1**). These VFDs **326** may be located alternatively on the motors **111** themselves or on the power end **103** of the pumps. One or more VFD **324** may be used per motor **111**.

All of the various components within the electric drive pump system **101/201** may be part of an integrated, self-contained single unit that makes up trailer unit **301**. The self-sufficient nature of the unit **301** decreases time spent on deployment, departure, and redeployment efforts. The enclosure of the trailer system **301** is modular and allows for one or more of the enclosure panels **314** to be removed in various combinations for greater access to the fluid end **108** (FIG. **1**) and power end **103** (FIG. **1**) components when necessary. Motors for ancillary systems and components may be electric or hydraulic. For, example, the electric motors (not shown) may be provided to operate the fans **320**, and the radiator pack **307** or other enclosure panels **314** may be pivoted with a hydraulic actuator.

During deployment, the trailer's open configuration (FIG. **22**) can fold together to form one solid outer body (FIG. **21**). Further minimizing its footprint and increasing transit efficiency, the hydraulically actuated enclosure panels **314** create a trailer system **301** that achieves a state of highspeed/low-drag.

Referring now also to FIG. **24** in the drawings, an alternate embodiment of a motor **401** is illustrated. Electric drive motor **401** is similar in form and function to motor **111**, and motor **401** is configured to be stackable. As depicted, motor **401** is an axial flux motor, which may be referred to as a "pancake" electric motor in some instances due to their generally flat shape relative to the axis of the motor. Each motor **401** in a stacked configuration may work together to amplify power and torque output numbers. One or more stacked motors **401** may be used similarly to and in place of each of the individual motors **111** illustrated individual motor **111** as seen in the referenced figures. In particular, a plurality of motors **401** may be staked together on a common drive shaft **141** in place of the stacked motors **111** illustrated in FIG. **14**.

Thus, a hydraulic fracturing pump system has been described. In one or more embodiments, the hydraulic fracturing pump system comprises a trailer platform supported on a plurality of wheels; a frame supported on the trailer platform, the frame including a plurality of spaced apart support members fixed to the trailer platform; an electric drive pump system supported on the trailer platform within the frame, the electric drive pump system including a fluid end, a power end operably coupled to the fluid end to drive the fluid end, and a plurality of motors operably coupled to the power end to drive the power end; a control unit supported on the trailer platform, the control unit operable to regulate the operation of the motors; and one or more enclosure panels movably coupled between the support members to substantially enclose the electric drive pump system within the frame. In other embodiments, the hydraulic fracturing system includes a platform elevated above a ground surface; an electric drive pump system supported on the platform, the electric drive pump system including a fluid end, a power end operably coupled to the fluid end to drive the fluid end, and a plurality of motors operably coupled to the power end to drive the power end; a control unit supported on the platform, the control unit including at least one variable frequency drive operably coupled the plurality of motors to the to regulate the operation of the motors; and one or more enclosure panels movably coupled to the platform to substantially enclose the electric drive pump system on the platform. In yet other embodiments, the hydraulic fracturing pump system includes a power end including a crank shaft mounted therein, the crank shaft rotatable to drive one or more plungers engaging a fluid end; a drive shaft coupled to the crank shaft to provide rotary motion to the crank shaft; a plurality of axial flux motors operably engaged with the drive shaft, wherein each axial flux motor is operable to transmit a power and a torque to the drive shaft; and a control module operably coupled to the plurality of axial flux motors to regulate the power and the torque transmitted to the drive shaft. In other embodiments, the hydraulic fracturing pump system includes an electric drive pump system having a fluid end, a power end operably coupled to the fluid end to drive the fluid end, the power end including a crank shaft; at least two axial flux motors coupled to the crank shaft; and a control module operably coupled to the axial flux motors to individually control the at least two axial flux motors. In still yet other embodiments, the hydraulic fracturing pump system includes a power end in which a crank shaft is rotatably mounted, the crank shaft extending between a first and second end, a fluid end coupled to the power end, the fluid end having at least one inlet and at least one outlet and at least one reciprocal plunger mounted in the power end, the plunger engaging the crank shaft of the power end; and a transmission assembly coupled to each end of the crank shaft, wherein each transmission assembly comprises at least two axial flux motors. In other embodiments, an electric drive pump system is provided and includes a power end including a crank shaft mounted therein, the crank shaft rotatable to drive one or more plungers engaging a fluid end; a drive shaft coupled to the crank shaft to provide rotary motion to the crank shaft; a plurality of axial flux motors operably engaged with the drive shaft, wherein each axial flux motor is operable to transmit a power and a torque to the drive shaft; and a control module operably coupled to the plurality of axial flux motors to regulate the power and the torque transmitted to the drive shaft. In other embodiments, the electric drive pump system includes a fluid end, a power end operably coupled to the fluid end to drive the fluid end, the power end including a crank shaft; at least two axial flux motors coupled to the crank shaft; and a control module operably coupled to the axial flux motors to individually control the at least two axial flux motors. In still yet other embodiments, the electric drive pump system includes a power end in which a crank shaft is rotatably mounted, the crank shaft extending between a first and second end, a fluid end coupled to the power end, the fluid end having at least one inlet and at least one outlet and at least one reciprocal plunger mounted in the power end, the plunger engaging the crank shaft of the power end; and a transmission assembly coupled to each end of the crank shaft, wherein each transmission assembly comprises at least two axial flux motors.

For any of the foregoing embodiments, the hydraulic fracturing pump system may include any one of the following elements, alone or in combination with any other elements:

- one or more enclosure panels includes a radiator pack coupled to an upper support member of the frame, wherein the radiator pack includes one or more fans operable to remove heat from the electric drive pump system.
- the radiator pack is pivotably coupled to the frame and supportable in a plurality of distinct angular positions with respect to the frame.
- the one or more fans are reversible to clear debris from the trailer
- the one or more enclosure panels includes a walkway pivotally coupled to the trailer platform.
- the walkway is hydraulically actuatable to move between an open configuration and a closed configuration with respect to the frame.
- the control unit comprises a telematics control unit operably coupled to the electric drive pump system to receive information regarding the operation of the electric drive pump system and transmit the information to a remote location.
- the telematics control unit includes at least one variable frequency drive operably coupled the plurality of motors to the to regulate the operation of the motors.
- the plurality of motors includes a plurality of axial flux motors coupled to a common drive shaft.
- storage containers supported beneath the trailer platform.
- an interior of the trailer between the one or more enclosure panels is climate controlled.
- the one or more enclosure panels includes at least one of the group consisting of a radiator pack and a walkway pivotally coupled between a closed configuration and an open configuration.
- the walkway or radiator pack is hydraulically actuatable to move between the open and the closed configurations.
- the plurality of motors comprises a stack of axial flux motors coupled to a common drive shaft.
- the control unit is operable to regulate a power and a torque transmitted to the common drive shaft by the stack of axial flux motors.
- the fluid end and power end are supported on a common trailer platform and substantially enclosed by a plurality of enclosure panels on the trailer platform.
- the drive shaft is one of a plurality of drive shafts operably coupled to the crank shaft, and wherein each of the plurality of drive shafts is operably associated with a stack of axial flux motors.
- a gearbox operably coupled between the crank shaft and the plurality of drive shafts.
- the crank shaft has a first end and a second end, and at least one axial flux motor is coupled to the first end of the crank shaft and at least one axial flux motor is coupled to the second end of the crank shaft.
- a plurality axial flux motors are coupled to the first end of the crank shaft and a plurality of axial flux motors are coupled to the second end of the crank shaft.
- the control module is configured to individually control each axial flux motor.
- a gearbox coupled between the crank shaft and the plurality of axial flux motors at an end of the crank shaft.
- a gearbox coupled between the crank shaft and the plurality of axial flux motors at each end of the crank shaft.
- a trailer on which the electric drive pump system is mounted.
- a skid on which the electric drive pump system is mounted.
- the control module comprises a telematics control unit operably coupled to the electric drive pump system to receive information regarding the operation of the electric drive pump system and transmit the information to a remote location.
- at least one variable frequency drive operably coupled the plurality of motors to regulate the operation of the motors.
- a control module operably coupled to the axial flux motors of at least one transmission assembly to individually control the at least two axial flux motors of the transmission assembly.
- a control module operably coupled to the axial flux motors of each transmission assembly to individually control each axial flux motor.
- each transmission assembly further comprises a gearbox coupled between the crank shaft and the at least two axial flux motors at an end of the crank shaft.
- each transmission assembly comprises a plurality of axial flux motors coupled to the crank shaft end.
- the axial flux motors of a transmission assembly are spaced apart from one another about the crank shaft end.
- each axial flux motor has a driveshaft and the axial flux motors of a transmission assembly are stacked so the driveshafts of at least two axial flux motors are coaxial.
- the control module comprises a telematics control unit operably coupled to the electric drive pump system to receive information regarding the operation of the electric drive pump system and transmit the information to a remote location.
- at least one variable frequency drive operably coupled at least two motors to regulate the operation of the motors.

It is apparent that an invention with significant advantages has been described and illustrated. The particular embodiments disclosed above are illustrative only, as the invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. It is therefore evident that the particular embodiments disclosed above may be altered or modified, and all such variations are considered within the scope and spirit of the invention. Accordingly, the protection sought herein is as set forth in the description. Although the present invention is shown in a limited number of forms, it is not limited to just these forms, but is amenable to various changes and modifications without departing from the spirit thereof.

What is claimed is:

1. A hydraulic fracturing pump system, comprising:

a trailer platform having an upper surface and supported on a plurality of wheels;

a frame supported on the trailer platform and extending vertically upward above the upper surface of the trailer platform, the frame including a plurality of spaced apart support members fixed to the trailer platform;

an electric drive pump system supported on the upper surface of the trailer platform within the frame, the electric drive pump system including a fluid end, a power end operably coupled to the fluid end to drive the fluid end, and a plurality of separate electric motors operably coupled to the power end to drive the power end, wherein the power end has a driveshaft extending along a driveshaft axis and the plurality of electric motors are arranged radially about the driveshaft axis but spaced radially outward apart from the driveshaft axis;

a control unit supported on the trailer platform, the control unit operable to regulate the operation of the electric motors; and

one or more movable enclosure panels coupled to the frame and movable relative to the frame to enclose at least a portion of the electric drive pump system within the frame, wherein the one or more enclosure panels includes an upper enclosure panel comprising a radiator pack, the upper enclosure panel coupled to an upper support member of the frame, wherein the radiator pack includes one or more fans operable to remove heat from the electric drive pump system.

2. The system according to claim **1**, wherein the upper enclosure panel is movable relative to the frame so that the radiator pack can be pivoted to a plurality of distinct angular positions with respect to the frame.

3. The system according to claim **1**, wherein the one or more fans are reversible to clear debris.

4. The system according to claim **1**, wherein the one or more enclosure panels includes a walkway, wherein the walkway pivots between a horizontal orientation and a vertical orientation relative to the upper surface of the trailer platform.

5. The system according to claim **1**, wherein the control unit comprises a telematics control unit operably coupled to the electric drive pump system to receive information regarding the operation of the electric drive pump system and transmit the information to a remote location.

6. The system according to claim **5**, wherein the telematics control unit includes at least one variable frequency drive operably coupled to the plurality of electric motors to regulate the operation of the plurality of electric motors.

7. The system according to claim **6**, wherein one or more of the plurality of electric motors includes a plurality of axial flux electric motors coupled to a common electric motor drive shaft.

8. The system according to claim **1**, further comprising storage containers supported beneath the trailer platform.

9. The system according to claim **1**, wherein an interior of the frame between the one or more movable enclosure panels is climate controlled.

10. A hydraulic fracturing pump system, comprising:

a platform elevated above a ground surface, the platform having an upper surface;

an electric drive pump system supported on the upper surface of the platform within the frame, the electric drive pump system including a fluid end, a power end operably coupled to the fluid end to drive the fluid end, and a plurality of separate electric motors operably coupled to the power end to drive the power end, wherein the power end has a driveshaft extending along a driveshaft axis and the plurality of electric motors are arranged radially so as to be radially spaced apart from the driveshaft axis;

a control unit supported on the upper surface of the platform, the control unit including at least one variable frequency drive operably coupled to the plurality of electric motors to regulate the operation of the plurality of electric motors; and

one or more movable enclosure panels coupled to the platform and movable relative to the platform to enclose or cover at least a portion of the platform, wherein the one or more enclosure panels includes an enclosure panel comprising a radiator pack, and wherein the radiator pack includes one or more fans operable to remove heat from the electric drive pump system.

11. The system according to claim **10**, wherein the one or more enclosure panels includes at least one of the group consisting of a radiator pack and a walkway and pivotable relative to the trailer platform between a closed configuration and an open configuration.

12. The system according to claim **10**, wherein one or more of the plurality of electric motors comprises two or more axial flux electric motors coupled to a common electric motor drive shaft.

13. The system according to claim **12**, wherein the control unit is operable to regulate a power and a torque transmitted to the common drive shaft by the two or more axial flux electric motors.

14. A hydraulic fracturing pump system, comprising:

an electric drive pump system having a fluid end, a power end operably coupled to the fluid end to drive the fluid end, the power end including a crank shaft;

at least two axial flux electric motors coupled to the crank shaft;

a control module operably coupled to the axial flux electric motors to individually control the at least two axial flux electric motors;

a trailer or skid platform on which the electric drive pump system is mounted; and

one or more movable enclosure panels coupled to the platform and movable relative to the platform to cover at least a portion of the platform, wherein the one or more enclosure panels includes an enclosure panel comprising a radiator pack, and wherein the radiator pack includes one or more fans operable to remove heat from the electric drive pump system.

15. The hydraulic fracturing pump system of claim **14**, where the crank shaft has a first end and a second end, and at least one axial flux electric motor is coupled to the first end of the crank shaft and at least one axial flux electric motor is coupled to the second end of the crank shaft.

16. The hydraulic fracturing pump system of claim **15**, wherein the at least one axial flux motor coupled to the first end comprises a plurality of axial flux electric motors coupled to the first end of the crank shaft and wherein the at least one axial flux motor coupled to the second end comprises a plurality of axial flux electric motors coupled to the second end of the crank shaft.

17. The hydraulic fracturing pump system of claim **16**, wherein the control module is configured to individually control each of the plurality of axial flux electric motors at each of the first and second ends of the crank shaft.

18. The hydraulic fracturing pump system of claim **16**, further comprising a gearbox coupled between the crank shaft and the plurality of axial flux electric motors at an end of the crank shaft.

19. The hydraulic fracturing pump system of claim **14**, wherein each of the at least two axial flux electric motors are axially aligned adjacent one another along a common electric motor drive shaft at an end of the crank shaft.

20. The hydraulic fracturing pump system of claim **16**, wherein the control module comprises a telematics control unit operably coupled to the electric drive pump system to receive information regarding the operation of the electric drive pump system and transmit the information to a remote location.

21. The hydraulic fracturing pump system of claim **16**, further comprising at least one variable frequency drive operably coupled to the plurality of axial flux electric motors to regulate the operation of the axial flux electric motors.

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